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Sky and TELESCOPE

In This Issue:

The Story of VV Cephei

An Improved Planisphere

The Southern Sky

The Total Solar Eclipse of January 25, 1944

Stars for October

Vol. II, No. 12
OCTOBER, 1943
Whole Number 24
20 cents

The Small Magellanic Cloud and 47 Tucanae

The watch above is the Longines Chronograph of Clyde Pangborn. Today, it helps navigate bombers over the Atlantic. In 1931, when ocean flights were branded as fools' missions, it served a world-flight that made front page news. Pangborn flew to Europe, across Russia to Chitka and thence to Tokyo. There he was welcomed by the police and lodged in the Tokyo jail! Japan didn't like free-flying Yankees. ¶The matter was settled by a stiff fine and Pangborn non-stopped his plane to Wenatchee, Washington, U.S.A. Pangborn had blazed a trail to Tokyo. ¶It was he and the other pioneers of aviation who demonstrated the possibilities of the airplane. And Longines first pioneered the aviation timepieces which now, as then, are essential in air navigation.

*From documents in our files

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Sky and TELESCOPE

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The Editors Note . . .

FOR two months this column has carried a partial list of articles on astronomy and related sciences which have been published recently by other periodicals. The list is concluded here, to be taken up again when additional references have accumulated and space permits. Our selection has been arbitrary, and the list must not be considered complete.

Journal of the Royal Astronomical Society of Canada (Toronto, Ont.). Jan. '43 is Vol. XXXVII, No. 1.

Setting Up and Adjusting the Equatorial Reflecting Telescope. H. Boyd Brydon. Feb. and Apr. '43.

Recent Progress in Astronomy. Frank S. Hogg, Mar. '43.

Observations of Venus, 1938-42, and Their Interpretation. W. H. Haas and H. M. Johnson. Apr. and May-June '43.

Comets and Meteors. A. V. Madge. May-June '43.

The American Scholar (Phi Beta Kappa, New York). Winter 1942-43 is Vol. 12, No. 1.

Our Universe. Roy K. Marshall. Winter 1942-43.

WE and our readers are indebted to many professional astronomers and their observatories for both articles and illustrations which appear in this magazine. Perhaps some reader can do Dr. N. U. Mayall, of Lick Observatory, a return favor (several moon and nebulae photographs taken by Dr. Mayall have been used for our back covers) and receive a reward for the effort!

The problem is to find a source for the original reference of John Bevis' observations in 1731 of the Crab nebula (M1) which are referred to by Messier in his catalogue of 1781. Dr. Mayall says he has been looking for this for a long time, and offers as a reward a 14x17 print of any picture in the famous Lick Observatory album of celestial photographs.

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FRONT COVER: The Small Magellanic Cloud, from a photograph taken at Harvard's Southern Hemisphere station, with the brightest globular cluster, 47 Tucanae, included in the field. The Cloud is at a distance of about 84,000 light-years, and the diameter of its main portions is about 5,500 light-years. All of the stars in the photograph, except those between us and the Cloud, are considerably brighter than the sun. 47 Tucanae is such a large globular cluster, of total absolute magnitude about —11, that it may be considered a small galaxy in its own right. To the left of the Small Cloud is another globular cluster, N.G.C. 362.

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BACK COVER: The Large Magellanic Cloud, which, together with the Small Cloud, is considered by many to be a detached part of the Milky Way galaxy. It is some 75,000 light-years away, and the diameter of its main body is 10,000 light-years. This photograph was taken by S. I. Bailey with the 8-inch Bache telescope at Arequipa, Peru, in 1897, exposure, 7 hours. The Magellanic Clouds are within 25 degrees of the south celestial pole, so may be seen only from the torrid zone and the Southern Hemisphere.

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THE STORY OF VV CEPHEI

BY VICTOR GOEDICKE, *Yale University Observatory*

IN STUDYING the various stars which are of exceptional interest for astronomers, one cannot help but be struck by the diversity of difficulty in securing the essential facts. In one problem, the most erudite analysis may be required to extract its information, while in another the facts stand revealed at first inspection. VV Cephei is an example of the latter. The main features of this extraordinary system unfold themselves merely from a day-to-day inspection of the spectrograms, for anyone to see and understand.

And yet, there are several vital facts about the system which not only are not evident, but are so thoroughly hidden that they have so far defied the efforts of all investigators who have studied the star.

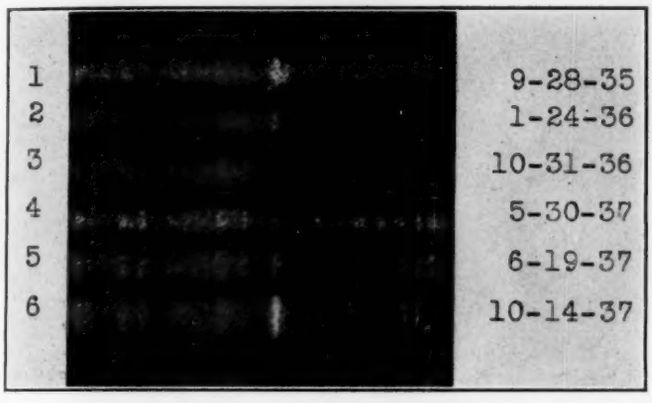


Plate I. The disappearance of Hβ emission during totality. On May 30, six weeks before the emergence of the B star, Hβ has begun to strengthen. All illustrations for this article are by courtesy of the Publications of the University of Michigan Observatory.

At first glance, the spectrum of VV Cephei is unusual by reason of the multiplicity of its components. It consists of the spectrum of an *M*2 giant, with a strong continuous spectrum in the ultraviolet, indicating the presence of a hot companion of probably *B* type. Also present is a set of iron emission lines, both permitted and forbidden, and a set of hydrogen emission lines, each divided into a red and a violet component, which vary in intensity in the way characteristic of *Be* variables. The spectrum also contains emission lines of ionized calcium and ionized titanium. The *M* star is irregularly variable in luminosity and radial velocity.

Let us pause here to review the physical conditions necessary for the production of emission lines. These lines appear whenever large numbers of electrons are cascading down through the successive atomic energy levels from the ionized state to the ground state. An electron in any one of the intermediate states will fall spontaneously to one of the lower states after a length of time which depends on chance but has a rigidly prescribed average value. This "mean life" of an electron in a given state is a very small fraction of a second for ordinary states, but there are a few states for which the mean life is very much longer.

The conditions for production of emission lines are, first, that enough short-wave radiation must be present to ionize a large number of atoms; second, that the atoms be left undisturbed for a period comparable to the mean life, so that the transitions have time to occur. If, for instance, an atom suffers a collision with another atom before it has radiated, the energy may simply be converted to thermal energy in the collision, and the emission line will not be radiated at all. For lines of low transition probabilities, there is the further danger that the atom will be struck by short-wave radiation before it has radiated, and the electron removed to a higher state, from which it will descend by a different series of jumps. Thus, the gas must be receiving short-wave radiation, but not too much of it, and the atoms must be so far apart that collisions are infrequent. If the emission line being considered has a *metastable* state for its upper level, then the radiation must be still weaker and the gas still rarer, since the mean life in the metastable state is still longer than for ordinary states. Such lines cannot be produced in the laboratory and are called *forbidden lines*.

The energy for the emission lines in VV Cephei must then be supplied by short-wave radiation from the *B* star, but the lines cannot originate at the surface of the star, because of the relatively high density and strong radiation there. They must arise instead in a region of lower density considerably removed from the surface, the more so in the case of the forbidden lines.

In 1936, Dr. Dean B. McLaughlin, of the University of Michigan Observatory, noted that the hydrogen emission lines had disappeared from the spectrum of this star, and that the ultraviolet region was much weaker than usual. He immediately interpreted this as evidence that the *B* star had been eclipsed by the *M* star, and, recognizing the unusual possibilities for analysis provided by an eclipse in so complex a system, he inaugurated a program of intense observation during the critical phases of the emergence. And so began the fascinating study of this extraordinary eclipse.

The fact that the hydrogen emission disappeared with the *B* star while the iron emission did not indicated that the former originated in a comparatively small region around the *B* star, while the latter originated in a much larger region, too large to be eclipsed or even perceptibly dimmed by the *M* star. Furthermore, by observing the reappearance of the hydrogen emission, it would be possible, from the interval by which this event preceded the reappearance of the *B* star, to determine with precision the size of the emission region.

Following McLaughlin's announcement of the eclipsing nature of the star, Dr. Sergei Gaposchkin examined the Harvard plates of the region and found confirmatory evidence of the eclipse. The light curve of the star showed three well-defined minima at intervals of 20.4 years, and indicated that the then current eclipse, which began early in 1936, would end around July, 1937.

On about May 12th, two months before the expected emergence of the *B* star, the Hβ emission line began to reappear, but the other hydrogen lines

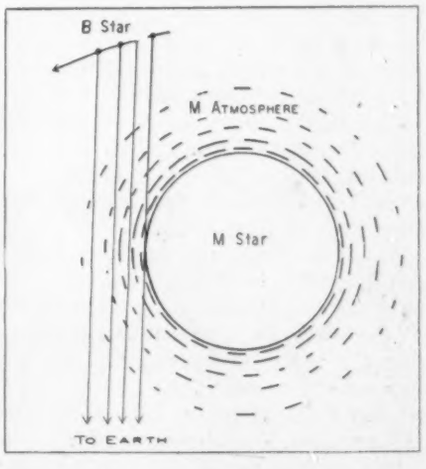


Fig. 1. As the B star emerges from eclipse, it shines through portions of the M atmosphere successively farther from the M star.

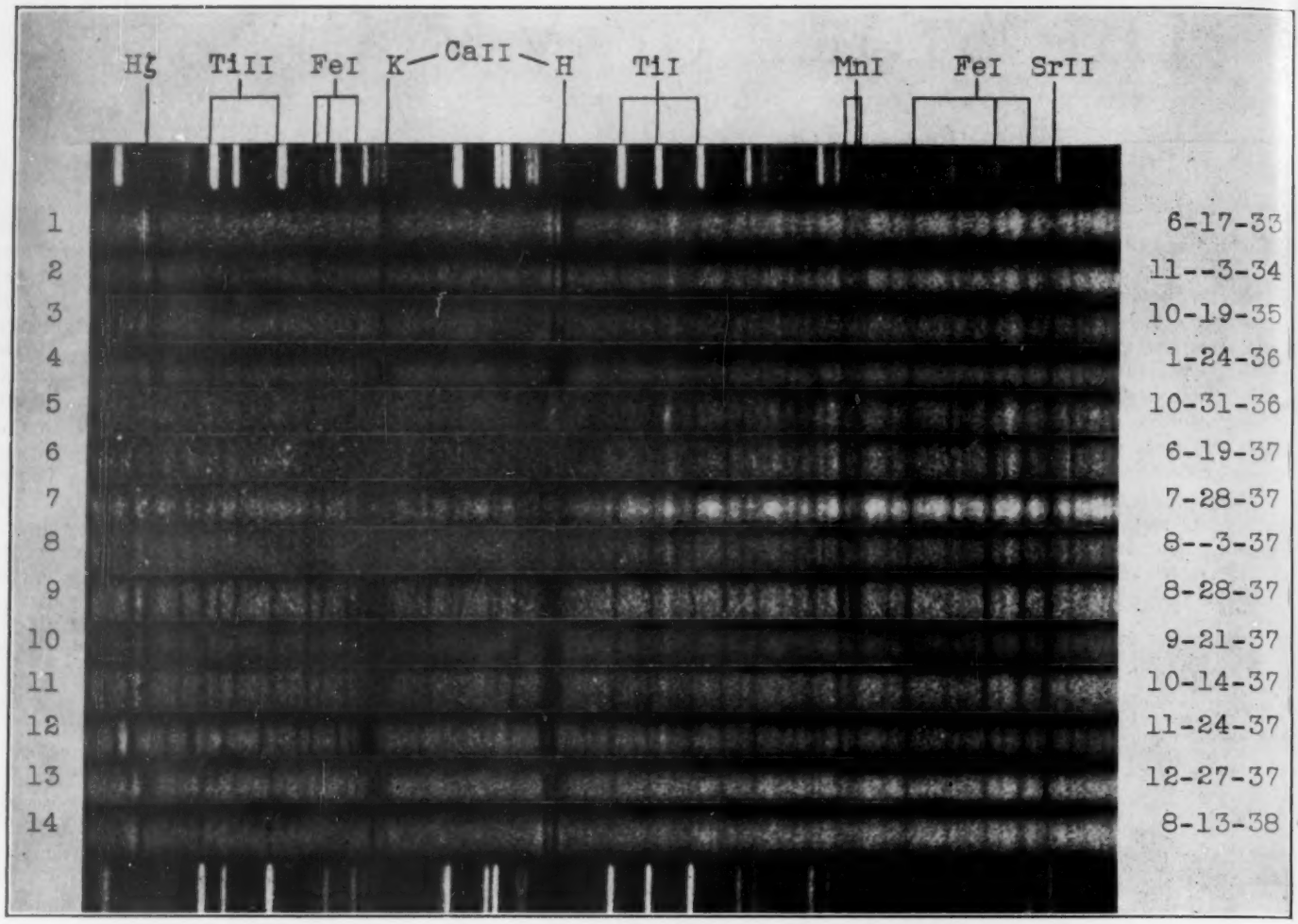


Plate II. The spectrum of VV Cephei near eclipse, from wave lengths 3880 to 4080. Spectrum 1 is the normal composite spectrum, before atmospheric effects have appeared. In 2, preceding eclipse by a year and a half, the earliest effects are visible in the strengthening of the TiII lines.

remained invisible. The Hγ line began to reappear on June 15th, and the further lines reappeared by July 13th. (The Hα line is beyond the wave-length range of the Ann Arbor spectrograms.) After July 13th, the ultraviolet began to strengthen, as the *B* star reappeared. The time of this reappearance could not be observed with precision from the spectra, since the Ann Arbor sky, believed by the local astronomers to be the worst in the world, frequently swallows up most of the ultraviolet in any case. However, this event was timed with precision by Gaposchkin, at Harvard, who noted that the light from the star increased steadily during the interval from July 12th to August 3rd.

If we attribute this increase of light to the emergence of the *B* star from behind the sharp limb of the *M* star, and if we make the reasonable assumption that the region of hydrogen emission is symmetrical around the *B* star, then it is clear that the region from which the Hβ emission is strong enough to be observed is a sphere of about seven times the radius of the *B* star; that of Hγ is four times that of the *B* star; and those of the further Balmer lines are not much larger than the *B* star itself.

Upon the emergence of the *B* star, the absorption spectrum in the region where the *B* star is strong underwent a striking change, due to the fact that the *B* star, having emerged from behind the *photosphere* of the *M* star, was now shining through its *atmosphere*. This phenomenon, discovered a few years earlier in the case of Zeta Aurigae, is a very rarely observed occurrence, and, from the point of view of astronomers, a very fortunate one.

If a physicist were asked to analyze a sample of a gas, to determine not only its chemical composition but also the degree of ionization and excitation of the various elements, his most powerful method would be to place a hot source of continuous spectrum behind the gas and examine the resulting absorption spectrum. Astronomers are physicists who cannot control their laboratory experiments; they are the ultimate opportunists of the physical scientists. And here is an unsurpassed opportunity—to analyze successively the regions of the *M* atmosphere through which the *B* star shines as it emerges farther and farther from eclipse.

The effects on the spectrum are rapid and dramatic. Early in July, 1937, it consists of the pure *M* spectrum (plus, of course, the iron emission lines); by the end of July the violet and ultraviolet regions have regained the strength which they had outside of eclipse, but instead of there being an almost entirely continuous spectrum, it is completely cut up by strong absorption lines. These lines are far stronger than the corresponding lines in a normal *M* spectrum, since the light from the *B* star traverses the *M* atmosphere twice, and obliquely. This phase is shown in spectrum number 7 of Plates II and III.

By early August, the numerous faint lines due to neutral vanadium (VI) have almost disappeared, while most of the other lines remain strong. Clearly, the neutral vanadium is confined primarily to a very thin layer above the photosphere, while the other elements extend to greater heights. By September, most of the neutral metallic lines (see iron (FeI), titanium (TiI), and manganese (MnI) in the illustrations) have weakened greatly, but the lines of the ionized elements are still strong. The beam from the *B* star has now cleared the lower levels of the *M* atmosphere and is traversing the upper levels where ionization is further advanced due to low

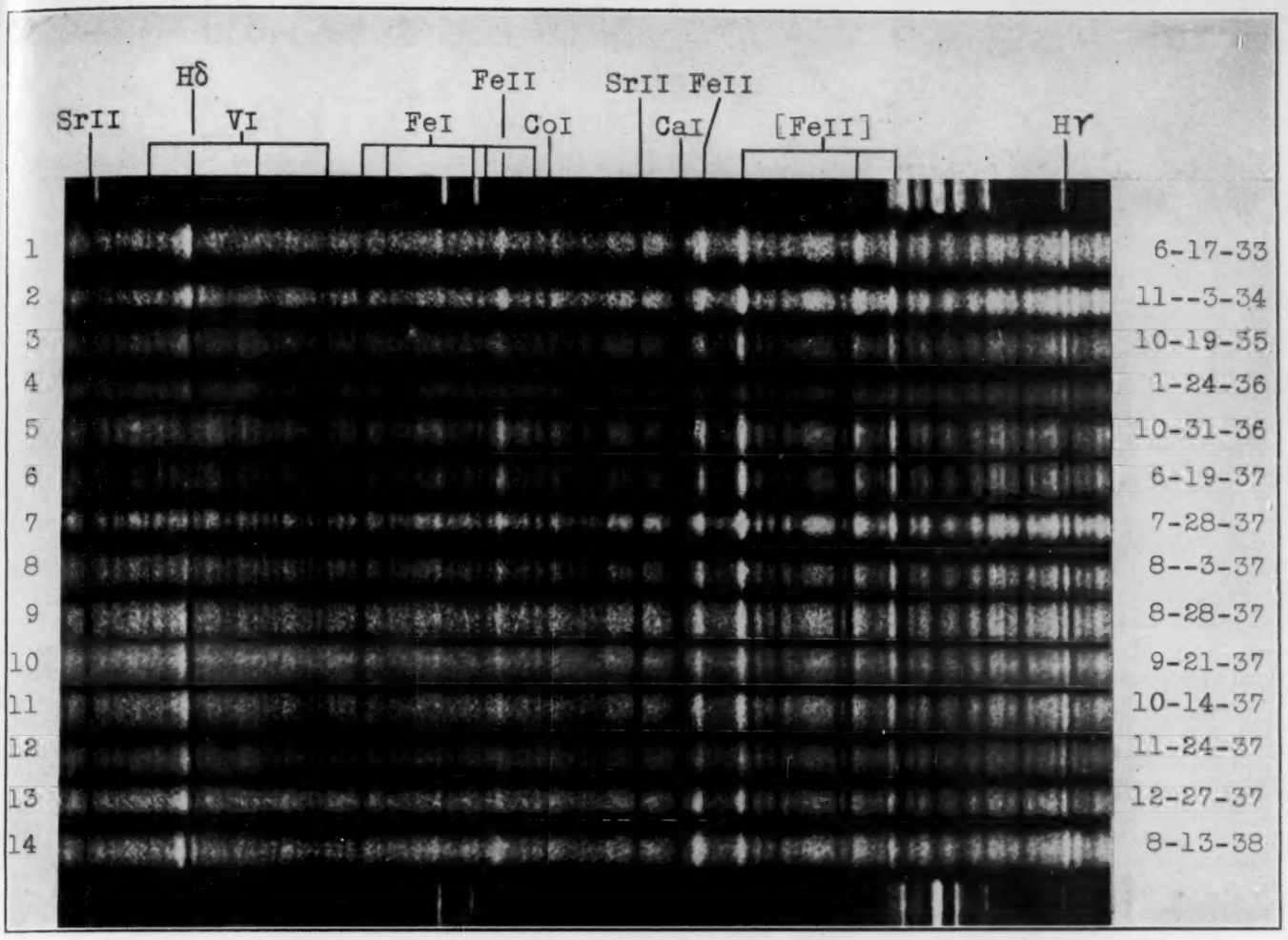


Plate III. The spectrum of VV Cephei near eclipse, from wave lengths 4070 to 4350. The SrII line is common to this plate and Plate II. The uppermost and lowest spectra are reference lines from a laboratory source.

density. By December, the neutral lines are almost normal, and the H and K lines of ionized calcium (CaII) have greatly weakened. The ionized titanium lines (TiII) alone remain appreciably stronger than normal. In August, 1938, these lines are still clearly evident (spectrum number 14), and in fact remain so until the end of 1938, a year and a half after the emergence of the *B* star!

Here, as in the case of the hydrogen emission, the observations await only a knowledge of the sizes of the stars and orbits to be translated into dimensions of the various components of the atmospheres. The orbits and dimensions of the system are obtained by the ordinary methods used for eclipsing binaries.

(If I may lay aside for a moment the role of an astronomer, I should like to comment that there is nothing more extraordinary than these "ordinary methods." Such a binary is seen or photographed as only a single point of light in the sky; from a study of the nature of that light, plus a record of its total quantity, we learn that it is not one star but two; we learn the size and shape of the orbits, the positions and velocities of the stars at any time in these orbits, their sizes, masses, temperatures, and compositions.)

There are in VV Cephei, however, several complications which deserve separate mention. First, the radial velocities of the *M* star represent the velocities, not of the center of mass of the star, but of its atmosphere, which approaches and recedes as the star pulsates. At present we can only draw a mean curve through the fluctuating measures of velocity, but it is to be hoped that after further observation, correlations with other ob-

(*Continued on page 20*)

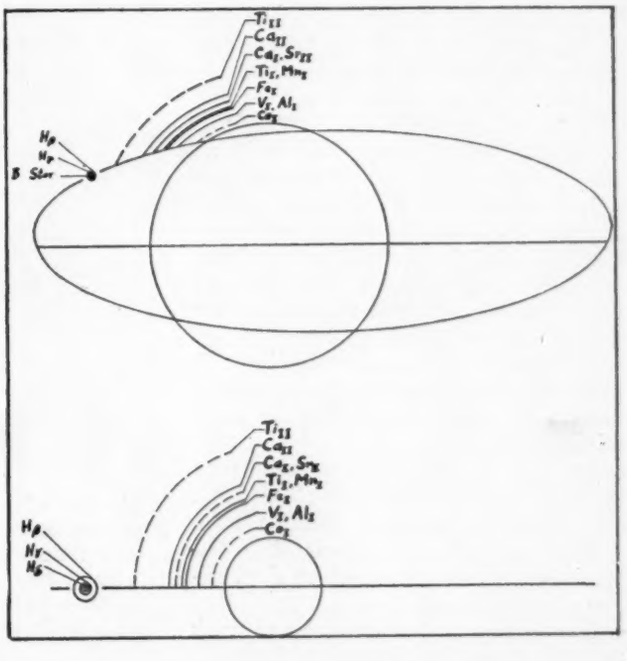


Fig. 2. The extents of the atmospheres surrounding the components of VV Cephei. Two extremes of size are presented here, with the probability that the correct value lies between them.

The planisphere is currently being used in pre-navigation classes, each student making his own settings.

An Improved Planisphere

By Oliver C. Collins, *University of Nebraska*

An illuminated planisphere with several unusual features has been of great assistance to our students at the University of Nebraska, during the past three years, in helping them to acquire a knowledge of the stars and constellations. It is now in use in our pre-navigation classes, where it is of particular value in that it registers closely not only the altitude and azimuth of each navigational star but also the instantaneous position of its substellar point.

The apparatus stands some 34 inches high on a base which is 20 inches wide by 11 inches deep. Conveniently portable, it can be used in daylight or in darkness, indoors or out, at any point where an electric outlet is available. It is of rugged construction, and has withstood the strain of vigorous operation at the hands of many hundreds of students, who appreciate it for the element of self-service which it affords.

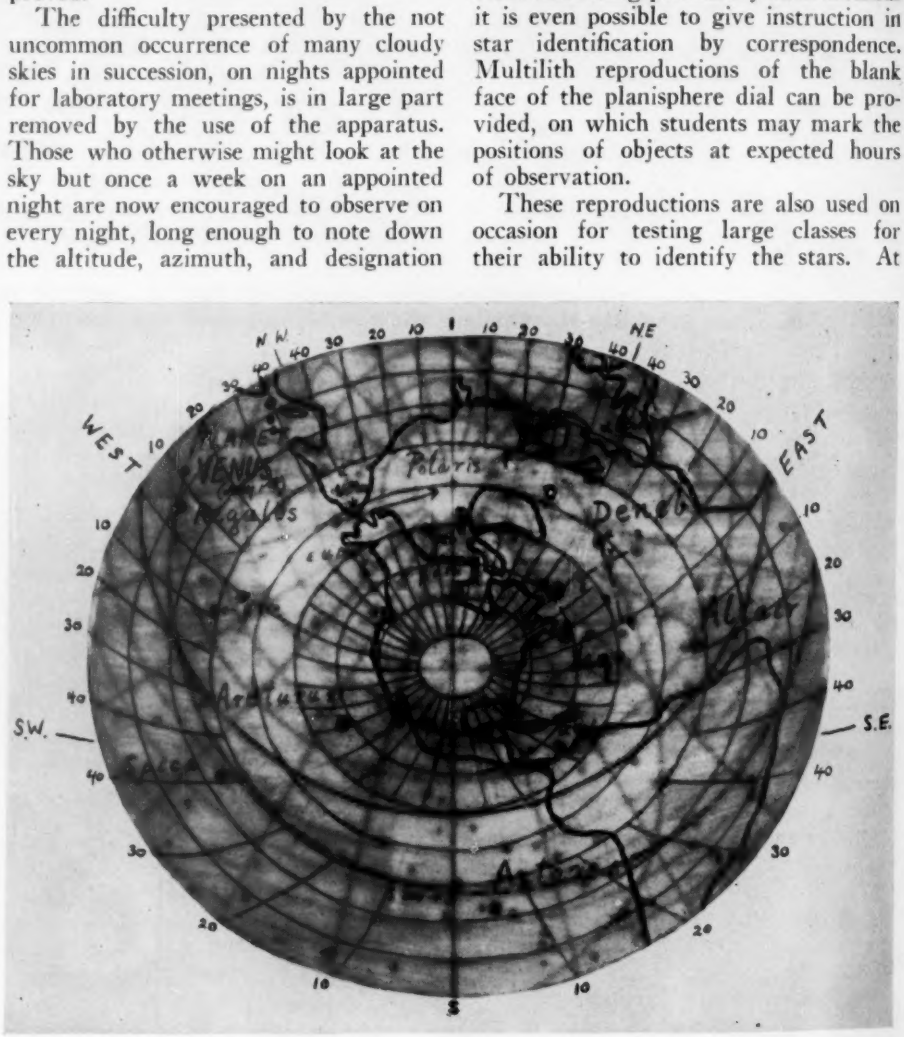
Compact and self-contained, with no loose parts or scales which can be mislaid, it incorporates in one apparatus the precision attainable in setting and measuring on a celestial sphere, together with the vastly greater facility of adjustment and inspection which is afforded by the planisphere type of presentation. A flat representation of the celestial sphere, in which the stars are plotted relative to a co-ordinate system centered on the north celestial pole, is drawn on a disk. This is partially masked and can be turned so as to reveal, at one time, only that half of the sky which is visible from a certain longitude, at a definite date and hour, in the latitude for which the horizon mask is made.

One important feature is the network of almucantars (for altitude) and verticals (for azimuth) which is permanently in position, and which permits reading off the horizontal co-ordinates of any object with far greater ease and speed than can be done on a sphere, yet with quite comparable accuracy. Time is saved also in that the positions for a sequence of many stars may be read in swift succession at one setting. This feature facilitates the acquisition of good judgment in estimating by eye from the sky the altitude and azimuth of each object seen, since these estimates can so readily be checked on the planisphere and subsequent estimates thereby improved.

The difficulty presented by the not uncommon occurrence of many cloudy skies in succession, on nights appointed for laboratory meetings, is in large part removed by the use of the apparatus. Those who otherwise might look at the sky but once a week on an appointed night are now encouraged to observe on every night, long enough to note down the altitude, azimuth, and designation of each of the brighter objects seen, even if the sky is only partially clear. The more nearly overcast the sky, the greater is the skill in identifying such objects as may show through; for celestial navigation there is great need for such skill.

Report forms are provided for such observations, and these can be used by each student independently at his own convenient times. These reports come to the observatory on the following day through the campus mail (an inter-office service) and are promptly checked and made available for return before the coming of another night. Thus, no error need long persist. By such methods it is even possible to give instruction in star identification by correspondence. Multilith reproductions of the blank face of the planisphere dial can be provided, on which students may mark the positions of objects at expected hours of observation.

These reproductions are also used on occasion for testing large classes for their ability to identify the stars. At



A view of the planisphere face shows the sky in projection on the surface of the earth at 16 hours sidereal time at Lincoln, Neb., on July 1st. The Central war time was about 10:50 p.m. (L.C.T., 9:23 p.m.). The star directions were correct not only for Lincoln at this time, but for any other place in the same latitude at the same local hour. Substellar positions were correct for this hour at Lincoln or for times at other places which correspond to this same instant.

such times, each student marks down star positions in altitude and azimuth as observed in the sky, to the best of his ability, together with the designation of the star. For checking these reports, which may relate to many various hours, a stencil is employed, which may be applied to each paper separately, or may be used on an entire stack of papers at one time if these papers are first turned to individual positions so that the stars should be in register on all. The stencil is a circular sheet of celluloid drilled with holes of sizes to correspond with the star magnitudes. True star positions may be indicated on the paper by marking through the holes with a pencil on single sheets, or with a penetrating spike for the purpose of marking on 100 or so sheets at one time.

Another improvement in the apparatus is that the fixed scale and the moving scale are each marked with both hour and date. Thus different hours may be quickly brought to any one fixed date or, when it is more convenient to do so, different dates may be set against a certain fixed hour.

Also, for each and every setting the local sidereal time is found at the lowest point on the rotating disk. In the illustration the setting is for sidereal 16 hours, which occurs at Lincoln, Neb., at all the different date and hour combinations of Central war time which may be read around the dial, and this fact obviates a certain measure of unnecessary computation. The feature is of value even to a professional astronomer in planning his observing program, which may call for catching certain objects at or near polar altitude, or in some other special position. Furthermore, the vertical circles are interrupted from altitudes 30 to 50 degrees in order to emphasize the almucantar of the pole and to assist the reading of other altitudes.

The incorporation of the geographic outlines on the face of the apparatus helps to familiarize the user with the facts relative to the substellar points; to make real to him by constant association the idea that the azimuth of each star is the azimuth of its substellar point, and that the zenith distance of each star is the angular distance on the earth's surface between the substellar point and his own position. When observations of star altitudes are made locally by sextant or other means, it is convenient to use our known position at the observatory as the assumed position for the purpose of computing location by means of Sumner lines. Then if the altitude has been well observed and corrected for refraction, these lines of position will intersect in a "fix" not far from our actual position at the center of this diagram.

The apparatus was inexpensive in construction, consisting merely of a wooden box having light within, controlled by a switch on the left side, and having a large round aperture in front covered by two glass disks. The disk on which the stars are plotted is mounted on a metal ring supported by three small flanged wheels, so as to be turned about its center by means of the crank attached to one of these wheels. The other disk does not rotate, but is held in a frame which is hinged at the top and clamped by a screw below. These two disks stand with a space of about 1/10 inch between them.

A side view of the device shows some of the details of construction.

The non-rotating disk carries the horizon mask and the altazimuth network. The deformation of the almucantar circles and of the azimuth directions is inherent in this type of instrument on account of the polar projection. This disk also carries the outline of geographic features for that half of the world which is within 90 degrees of the point of observation. Thus each star is shown in register with the place on the earth's surface where it is at the moment in the zenith.

The two glass disks were prepared by fine grinding with emery on both the surfaces of each disk. The star disk was marked with 10-degree declination circles on a uniform scale of 1 mm. = 1°, and with a system of hour-circle lines radiating from the pole at 15-degree intervals. These marks and the plotting of small circles of various sizes to represent the stars were all made on the back of this disk, as were also the curves to represent the ecliptic and the course of the Milky Way. The star circles, of sizes to correspond with magnitudes, were filled with colored inks to indicate spectral types. A single drop of clear varnish applied to each small circle smoothed the surface and caused the transmission of a bright image as seen from in front. The front of this disk was left entirely free for such erasable markings as might be desired from time to time to keep pace with the changing positions of planets and comets and the appearance of novae, and also for the indication of constellation figures and names or designations of stars as they might be required for study.

The hours are marked in pencil and may be erased and changed at each occurrence of a legislative change in standard time. The frosting of the fixed disk provides the mask required to hide the parts of the sky not above the horizon, while over the part desired clear the frosting was neutralized by means of a smooth coat of transparent varnish applied front and rear. A circular ring near the circumference of this disk was similarly rendered transparent by varnish in order that the hour numbers or the dates on the rotating disk might show through and be read against the dates or hour numbers on the fixed disk.

The various features here described have had ample trial and have been found to be very much worthwhile.

American Astronomical Society Meets for Cincinnati Observatory Centennial

ON NOVEMBER 5-7, 1943, the American Astronomical Society will meet at the University of Cincinnati and take part in the commemoration of the 100th anniversary of the founding of the Cincinnati Observatory. The invitation to the society was extended by Dr. Elliott Smith, director of the observatory.

The tentative schedule of events calls for the centennial program and reception in the Wilson Auditorium on Friday evening, November 5th. Dr. Raymond Walters, president of the University of Cincinnati, will welcome the society, whose president, Dr. Harlow Shapley, will then give an address.

On Saturday, the regular session for scientific papers will take place in the morning and afternoon, followed by the society dinner at the Netherland Plaza Hotel that evening. The dinner will be followed by brief talks by several Cincinnatians, probably including Mayor Stewart.

The society headquarters will be at the Netherland Plaza Hotel throughout the meeting. If necessary, there will be a session for papers on Sunday morning also.

Amateur Astronomers

NEW YORK AMATEURS START FALL ACTIVITIES

Classes conducted by the Amateur Astronomers Association for the 1943-44 season are beginning October 11th. The schedule includes:

Monday: *Physics Survey* — Clyde Myer.

Tuesday: *Elementary Astronomy* — Richard S. Dodson.

Thursday: *Mathematics Survey* — Max Trupin.

Alternate Fridays: *Advanced Astronomy* — Jane Davis. (Beginning October 22nd.)

Alternate Fridays: *Astronomical Photography* — Peter A. Leavens. (Beginning October 15th.)

These classes are held in the Roosevelt Memorial Building of the American Museum of Natural History.

Tuesday and Thursday: *Telescope Making Class* — Allyn J. Thompson. (Beginning November 9th.) This class is held in the Optical Division workshop, in the Hayden Planetarium.

Registration can be made at the first class night, or by mail to the secretary, except for the telescope making class, for which registration is open during the entire month of October at the Optical Division workshop. Classes (except telescope making) are open only to A.A.A. members.

The regular lecture meetings will be held the first Wednesday of each month from October 6th through May. These are in the Roosevelt Memorial Hall at 8 p.m. and are open to the public. Invited guest lecturers for the season include Dr. Peter van de Kamp (Swarthmore College), Dr. Jan Schilt (Columbia University), Dr. Clyde Fisher (Hayden Planetarium), Dr. Robert I. Wolff (City College), Armand Spitz (Franklin Institute), Hugh S. Rice (American Museum of Natural History), Leo Mattersdorf (vice-president, A.A.A.).

Outdoor observation meetings will be held the third Wednesday of each month, beginning October 20th, under the leadership of Hazel Boyd, A.A.A. vice-president. The group meets at 8 p.m. at the Roosevelt Memorial Building, Room 129.

Special events include the 6th annual dinner on April 19, 1944; the annual meeting of the Amateur Astronomers Association, May 3, 1944; the annual field trip, May 30th; convention of amateur astronomers, July 4th; the annual weekend, September 2-4, 1944.

Jane Davis has been appointed assistant secretary of the association, in addition to her duties as staff editor, in the preparation of the A.A.A.'s "Astronomical News Service," distributed nationwide to the press.

The trip to the Teaneck observatory of the Bergen County Astronomical Society on Saturday, September 4th, was a huge success. Forty members of the two societies spent the afternoon and evening in astronomical discussion (including a question bee). There were motion pictures of A.A.A. activities, a picnic supper, prestidigitation by Frank J. Rigney, and a talk by Frank Varela on "The Amateur Astronomer's Contributions to the War Effort." Representatives of the press and magazines were on hand to record the doings. The A.A.A. again thanks the B.C.A.S. for its hospitality and co-operation.

Contributions are being accepted for the fund set up to establish The Amateur Astronomers Medal. Details of the rules to govern the award will be published shortly.

GEORGE V. PLACHY, secretary
Amateur Astronomers Association
American Museum of Natural History
New York

PHILADELPHIA MEETING

At the October meeting of the Rittenhouse Astronomical Society, on the 15th, Dr. Peter van de Kamp, director of Sproul Observatory, and vice-president of the society, will speak on "The Photographic Double Star Work of Hertzsprung and Strand." The meeting will be held at The Franklin Institute.

NEW COMET FOUND

On September 14th, as this issue was going to press, an RCA message from Zurich, Switzerland, was received at Harvard College Observatory, telling of the discovery of a comet of the 8th magnitude, by Diamaca, presumably a Rumanian observer. Its position for the evening of September 9th was given as $8^h\ 35^m$, $+53°\ 01'$, and its motion was $12^m\ 43^s$ per day eastward and $2°\ 25'$ northward.

Until further observations are made, it is not possible to predict future positions of the comet. However, if its motion were assumed to be uniform and in a straight line (rather unlikely in one particular case) a week after discovery would have found it on a line between the pointers in the Big Dipper and the north star, about eight degrees from the pointers. Powerful binoculars would be required to reveal it, and caution must be observed to avoid confusing the comet with the numerous galaxies in this part of the sky.

REPORTS ON AURORAE

The centrally located sunspot of August 8th, pictured on page 2 of last month's issue, was accompanied by auroral displays, several of which have been reported in response to our statement that no such reports had yet been received.

Alan Koppelman, of Brooklyn, writes of a display visible through haze from about 15 miles northeast of Peekskill, N. Y., about 10 o'clock that evening. At the same time, an aurora of moderate intensity was observed by a number of people at Loon Lake, N. Y., reports H. H. Nordlinger, of New York City.

Activity has evidently continued, as several additional displays were seen in the early part of September, including one visible in and around Boston, and called spectacular.

Leo Mattersdorf, New York amateur, writes of an early September display: "Last Saturday, I was in Chesterfield, N. H., which is seven miles from Brattleboro, Vt., as the crow flies if it follows the road. At about nine o'clock, I noticed an aurora which was not very intense but was clearly visible. Rays shot up from the northern horizon about halfway to the pole star. Later . . . additional streamers could be seen in the northwest, some of which were visible to a point at about the lowest part of the Great Dipper."

Jesse A. Fitzpatrick, who writes the Observer's Page, tells us that although the New York papers reported that sunspots had caused a lot of radio interference from September 2nd through 6th, "something must be wrong, because there wasn't a sign of a spot all last week. I had an excellent view of the sun yesterday (the 5th), and it was as clean as though someone had washed it with soap and water."

A member of the Junior Astronomy Club, Charles Culvas, of Long Island City, N. Y., observed an aurora from his home for 15 or 20 minutes at about 8:30 p.m., September 8th. "I saw a semicircle of white light which was slowly rising from the northern horizon," writes Mr. Culvas.

A. A. V. S. O. ANNUAL MEETING

The 32nd annual meeting of the American Association of Variable Star Observers is scheduled for October 8-9, 1943, at Harvard College Observatory. Opening with a joint meeting with the Bond Club on Friday evening, the program continues with the regular business meeting and election of council members and officers on Saturday morning, followed by a session for papers in the afternoon. The annual dinner is announced for 7:30 p.m. on Saturday evening, October 9th.

BEGINNER'S PAGE

SPECTRA — IV

Stars With Extended Atmospheres

By Percy W. Witherell

THE SPECTROSCOPE has revealed the existence of stars with turbulent atmospheres that are pulsating, expanding, or rotating. The *pulsating* group was discussed in a previous article on variable stars, in the June issue.

Stars with *expanding* atmospheres are exemplified by the Wolf-Rayet group (W). This small class of less than 100 known galactic members shows wide bright lines on the background of a continuous spectrum of considerable intensity. Absorption lines sometimes appear on the violet side of the edges of the bright bands.

Bright emission bands of helium, carbon, and oxygen, are typical of one group of Wolf-Rayet stars designated WC, and helium, nitrogen, and oxygen make up another group called WN. In contrast to the usual abundance of hydrogen revealed by most spectra, the Wolf-Rayet stars show only very weak emission lines of that element.

A very hot, *O*-type star surrounded by a relatively transparent atmosphere which is expanding rapidly, and is constantly receiving fresh material from the central star, could produce the unique spectra of these stars. In August, we discussed the broadening of spectral lines by the combination of innumerable Doppler effects. Radiation from the hot gaseous atmosphere or shell surrounding a Wolf-Rayet star produces the bright emission lines. The integration of the rapid expansion of the atmosphere in all directions from the star broadens the emission into bands of width proportional to the expansion velocity.

The continuous spectrum is produced by the light directly from the central star, but as it passes through the envelope some of it is absorbed and the dark absorption lines are produced. But this absorption takes place in an arc of the shell which is nearest us, and therefore rapidly approaching us, so that the Doppler effect shifts the absorption lines toward the violet end of the spectrum, as previously mentioned.

Another group of stars similar to the Wolf-Rayet are known after their prototype as P Cygni stars. Among other differences, however, their expanding atmospheres are so opaque that no light seems to reach us directly from the central star.

These, and other kinds of hot *O* and *B* stars with bright lines in their spectra, are generally very bright, but distant objects. The Wolf-Rayet stars average about 2,000 times the luminosity of the sun. Some in the Large Magellanic Cloud are 10,000 times as bright as our own source of light. Little is known, on the other hand, about their masses and diameters. Lately, the discovery of this type of star in a few spectroscopic binaries has revealed some information which gives encouragement to the solution of some of the mysteries of these interesting distant objects. It is probable that the above model of Wolf-Rayet stars may need to become a bit more complex, as our knowledge increases.

It is of interest that the nuclei of some planetary nebulae are similar to the Wolf-Rayet stars, so that the latter are sometimes described as miniature planetary nebulae. The P Cygni stars and the Wolf-Rayet stars are also related spectrally to the novae, but their actual physical characteristics appear to be quite different, both in size and mass.

The stars with extensive *rotating* atmospheres include some very peculiar specimens. Beta Lyrae is a curious system that has attracted much attention. This binary has a bright *B*9 primary of mass 50 times that of the sun, with a fainter companion of type *F* revolving about it. It has been suggested (*Sky and Telescope*, March, 1942) that both components are enclosed in a gaseous shell; that material is constantly flowing from the massive star around its companion; that some of these gases do not return but are ejected into space; that this latter material is forming an ever-growing ring about the pair.

Similar methods of interpretation of spectra have shown that the shell about the star Zeta Tauri is about five times the radius of the central star.

There are other stars for which satisfactory solutions or models are yet to be proposed. Among these are the well-known Gamma Cassiopeiae and Phi Persei. Needless to say, the future revelations from odd spectra are very intriguing.

Sauce for the Gander

READERS are asked to send in questions, from which this editor will select the best each month to answer here. The last question is left unanswered, but the reader should be able to find the answer for himself. This month's questions are from Stephen H. Forbes, Bryn Mawr, Pa., and Arthur T. Ward, Riverside, Cal.

Q. Does the angle at which the sun's rays strike Venus have any effect upon that planet's albedo? If there is an effect, would it make the date of Venus' greatest brilliance as seen from the earth appreciably different from what the date would be if the albedo were constant for all angles of reflection of the sun's light from Venus?

A. Theoretically, yes. The amount of light reflected from a surface will depend upon the angle at which the light strikes it, and this is true even for a gaseous mass reflecting individual light rays almost at random. But the difference is negligible, and would be lost in the much greater variations due to local changes in cloud structure. The effect upon refraction of light would be somewhat more important in some positions, as may be inferred from a consideration of the red coloration of the moon during an eclipse, where the color is due to the refraction of sunlight by the earth's atmosphere.

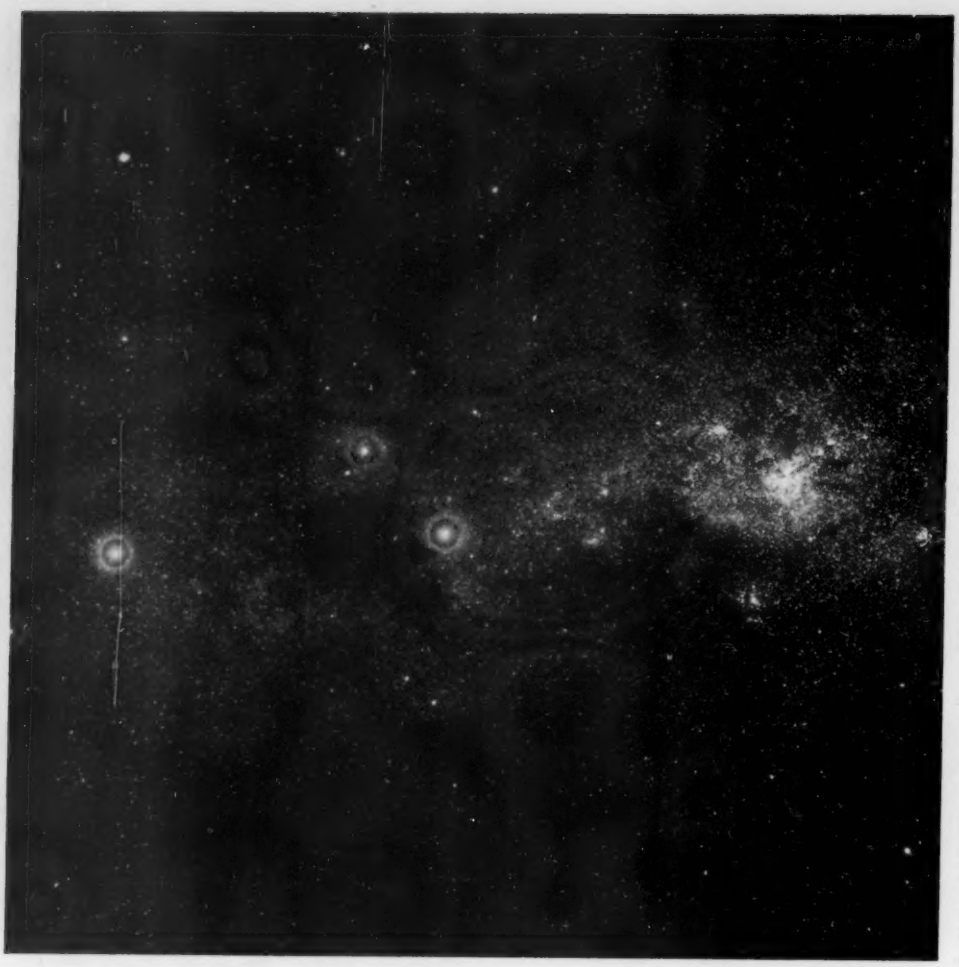
Q. If centrifugal force causes the equatorial bulges on the earth, Jupiter, and Saturn, why is there no such equatorial bulge on the sun?

A. The sun's rotation takes place in from about 25 to 34 days, depending upon the latitude of the solar region observed. Its circumference is about 108 times that of the earth, so that the actual speed of a particle at its equator is a little more than four times that at the earth's equator. The speed, combined with the curvature of the surface, gives a particle centrifugal acceleration amounting to 3.4 centimeters per second each second at the earth's equator. But the curvature on the sun is much less, and its surface gravity much more (about 26 times), so not only is the centrifugal acceleration less than on the earth, but the force overcoming it is much greater. At present, no observed equatorial bulge exists (although some older observations led to a different result), but it is probable that the sun has one, however slight. It must be remembered that the measurement of a gaseous incandescent body is extremely difficult, and the "seeing" is almost never satisfactory for observations of this type.

Q. Is the equatorial bulge of Jupiter visible in a small telescope?

WHEN previous mention of the "blue moon" was made, it coincided with the appearance in the **Proceedings** of the United States Naval Institute of a reference to a British Admiralty recording of the phenomenon in the last century. Readers have written to mention other occurrences: Francis D. Chapin, of Saco, Me., reports an observation of a blue moon at Rumford, Me., probably in the winter of 1930. Frederick A. Stebbins, of Springfield, Mass., reports an occurrence at Sugar Hill, N. H., in the summer months sometime in 1914-1918. Joseph Toniutti, of Chattanooga, Tenn., states a blue moon appeared two nights in succession in Port Arthur, Tex., in 1934. These three correspondents describe the color as "blue with a slight reddish fringe on the inner circle of the crescent," "steel blue," and "blue-green," respectively.

L. J. LAFLEUR
Antioch College
Yellow Springs, Ohio



The southern sky contains some of the best parts of the Milky Way. Cut in half on the left edge is the image of Alpha Centauri, and to the right and above it is Beta Centauri. These two stars point to Gamma Crucis, which appears faint because of its red color. Alpha and Beta Crucis are just below it, bright stars close to the very dark Coalsack. On the right is the nebulosity surrounding Eta Carinae, and in the upper left corner is bright Omega Centauri, the well-known globular cluster. Harvard Observatory photo.

THE SOUTHERN SKY

By William H. Barton, Jr.

SOMEONE compared astronomy with a golden thread running through history connecting all ages and all peoples. The sky has been a common meeting ground for people all over the world and in all periods of time. Today, with so many people in unfamiliar places, the sky is a link with homeland and friends. A famous theater critic told the writer once that he had a rendezvous with his absent wife every evening. At a given hour each of them looked at Venus, then the evening star, and thought of the other.

Our boys are scattered over the face of the earth, in the Aleutians, in the islands of the southwest Pacific, in tiny Atlantic outposts. They are in places we never heard of before the war, Guadalcanal, Attu, Buna, Murmansk. Yet they see nearly the same stars that we see.

But even though the boy from Brooklyn, N. Y., or Benton, Ark., or Middlebury, Vt., knew his home sky, he would find some new stars when he arrived at Honolulu, or Port Moresby. From the latter place he would see all of the southern sky.

The term "southern sky" is an indefinite one. Strictly speaking, it should encompass the stars below the equator of the sky, just as the Southern Hemisphere on the earth is that part lying south of the equator. In New York, Arkansas, or Vermont, however, the observer can see a great portion of the southern sky. From latitude 40° north, stars 50 degrees south of the celestial equator are visible—including more than three fourths of the area of the southern sky.

Yet in that fourth quarter many beautiful and interesting stars and star groups are concealed, and adjacent groups, such as the Scorpion, Sagittarius, and Canis Major, are never seen to best advantage from mid-northern latitudes. When our soldier goes south, the remaining southern stars are gradually revealed to him. But when he gets to Wellington, New Zealand, a corresponding quarter of the northern stars is hidden: the Big and Little Dippers, Cassiopeia, Cepheus, and Draco.

So let us go south with our soldier friend and study the sky with him. If he takes departure from San Francisco at dusk in the middle of October, he sees the Northern Cross almost exactly overhead, in the Milky Way. Along that luminous band toward the southwest he can see Altair in Aquila, and low on the horizon, Sagittarius.

The next night at the same hour he sees Sagittarius higher while the Northern Cross is lower. This latter group, part of the constellation Cygnus, is an important one for him to study, for by the time he reaches Honolulu, the soldier will be expecting to see the Southern Cross, about which he has heard so much, and will want to compare it with its northern counterpart. But he will not see the Southern Cross at Honolulu, for in October it is in the daytime sky there, crossing the meridian almost at noon. In a month's time, however, it will be visible in the eastern sky at dawn, very low in the southeast. And gradually, as the soldier continues his voyage southward and the season advances, he will observe those other important and beautiful stars that we associate with the southland.

The Southern Cross is one of the most famous star groups in the sky. It consists of four bright stars, lettered Alpha, Beta, Gamma, Delta. Only one bears a particular name. Alpha is called Acrux, a coined name that appears in Burritt's *Atlas* and was probably original with him. The whole constellation bears the official name Crux. To the ancients it was part of Centaurus, its neighbor that surrounds it on three sides. Acrux, the brightest star, is at the foot of the Cross and is of magnitude 1.3, about as bright as Betelgeuse. It is really a double star, one component of magnitude 1.6, the other, 2.1. Gamma Crucis, at the top of the Cross, has a magnitude of 1.6, while Beta is 1.5, and Delta, 3.1. These latter two form the crosspiece. Nearby, a 4th-magnitude star slightly interferes with the symmetry of the group. These are "the Cross," but the constellation has 49 other stars visible to the naked eye.

It is believed that Royer, in 1679, was the first to make a constellation out of these stars, but for nearly two centuries before, hints of its separation from Centaurus may be found.

For 12 centuries, from Pliny to Dante, the poets neglected it. Dante was much interested in the stars. Perhaps from learned travelers, he picked up a great deal of sky lore, and his writings reflect a broader knowledge than one would expect a 14th-century

poet to have. In Longfellow's translation of Dante's *Purgatorio,* the Cross is referred to as follows:

. . . and fixed my mind
Upon the other pole and saw four stars
Ne'er seen before save by the primal people.

Vespucci claims to have been the first European to have seen the Cross. He did not name it Crux, however, but called it Mandorla. This is the name given the halo that surrounds the heads of saints in old Italian art. Vasco da Gama also claims the Cross as a discovery.

In the 16th century, writers frequently mention this group of stars. It was even referred to as the celestial clock. It does, like the Big Dipper, serve as a star clock for those who know how to use it. Its top and bottom stars form pointers to the south pole of the sky, but because there is no bright star to mark it, this point of the heavens is not so easy to locate as the north celestial pole.

Near the Cross is a region famous for its lack of stars—the Coalsack. It is a region approximately eight degrees by five in which the eye can detect only one star, and a very dim one at that. This area, large enough to hold 150 moons placed side by side, was first noted by Pinzon in 1499. It is by no means unique. Near our own Northern Cross there is another, generally known as the Northern Coalsack. Webb's famous *Celestial Objects for Common Telescopes* lists 33 such starless fields visible to northern observers.

For many years such areas were thought to be holes through which we could look out into the emptiness of space, and this idea prevailed up to 1910. Today, we know them to be dark or obscuring nebulae. E. E. Barnard, at Yerkes Observatory, found unmistakable evidence that they were vast clouds of cosmic dust. Like a dark storm cutting off the light of the sun, these nebulae blot out the stars that are more distant than they. All along the Milky Way these rifts are observable, long, dark streaks in that bright field of stars.

In contrast to these dark spots, in the southern sky are two striking, bright nebulous objects, appearing like detached portions of the Milky Way. These are the Magellanic Clouds, the Large and the Small. They are great star clouds away out in space. The larger one is estimated by Dr. Harlow Shapley to be at a distance of about 75,000 light-years and the smaller at 84,000.

The unaided eye sees the Magellanic Clouds merely as bright, hazy spots, but telescopes break them down into stars—as many as half a million can be detected in the Small Magellanic Cloud. Each one is a sun, not unlike our own sun, except that perhaps 10,000 of them are more than 1,000 times as bright as the sun, and 400 may be as much as 10,000 times as bright. If we were 84,000 light-years distant from our own sun, it would be barely visible in our largest telescopes.

A close-up of 47 Tucanae, the largest and brightest globular cluster. As the front cover shows, it appears near the Small Magellanic Cloud, but is less than one third as far away from us.

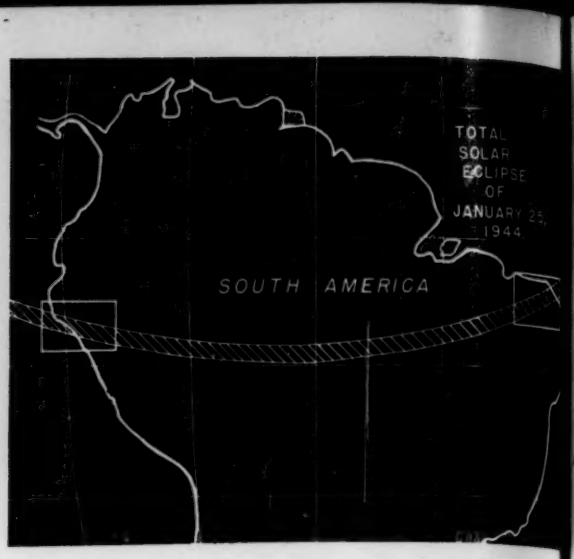
These clouds are the most distant of the objects that we can see plainly and locate easily with the unaided eye. And, in contrast, the nearest star (excluding the sun) is not situated far from them in the sky. The constellation Centaurus contains this star that bears no particular name. It is merely Alpha Centauri. The light from this star requires about 4 1/3 years to reach us, because the star is about 26,000,000,000,000 miles away, nearly 300,000 times as far away as the sun.

Alpha Centauri, as well as three stars in the Cross, are counted among the 55 navigational stars listed in the *American Nautical Almanac.* Two others, Achernar and Acamar, belong in Eridanus, the River. This is a long, winding constellation something like Draco in the north. It begins near Orion and extends in a southwesterly direction.

Canopus, another important navigation star, is just below the horizon of those who live in the middle latitudes of the United States. It belongs in that large constellation formerly known as Argo Navis, out of which were made Carina, Vela, Pyxis, and Puppis. Here, too, you will find several other navigation stars, Al Suhail, Epsilon Carinae (Argus), and Miaplacidus. These are all in a rather large area just west of Crux and south of our famous Dog Star, which, incidentally, is a southern star too.

You may have a rendezvous with your soldier friend if you will select a star that you can both see at the same time. But don't forget about the time. Someone was telling the writer of doing this and forgetting that 9 o'clock in one place is not 9 o'clock somewhere else. You may even find it impossible to observe the same star. There is a nine-hour difference between New York and the islands of the southwest Pacific; war time adds another hour. It may, therefore, be daylight where you are before it is dark where the soldier is.

Even the stars are busy these days, guiding ships and planes, orienting guns, determining time, but they are not too busy to carry your wish. I know what that wish will be. And don't forget that the stars are helping to make it come true.



THE TOTAL SOLAR ECLIPSE

BY CHARLES H. SMILEY, *Ladd Observatory*

The thoughts and facts presented here concerning an eclipse which may seem distant in both time and place may nevertheless interest our North American readers. In addition, we hope that the charts above, prepared by the author, will be of use to South American observers of the eclipse itself.

AS THE umbra of the total solar eclipse of next January moves east across South America and later across western Africa, the shadow will probably find not a single eclipse expedition from the United States anywhere along its path. Even if the European war should be over, the Pacific war will remain to be fought.

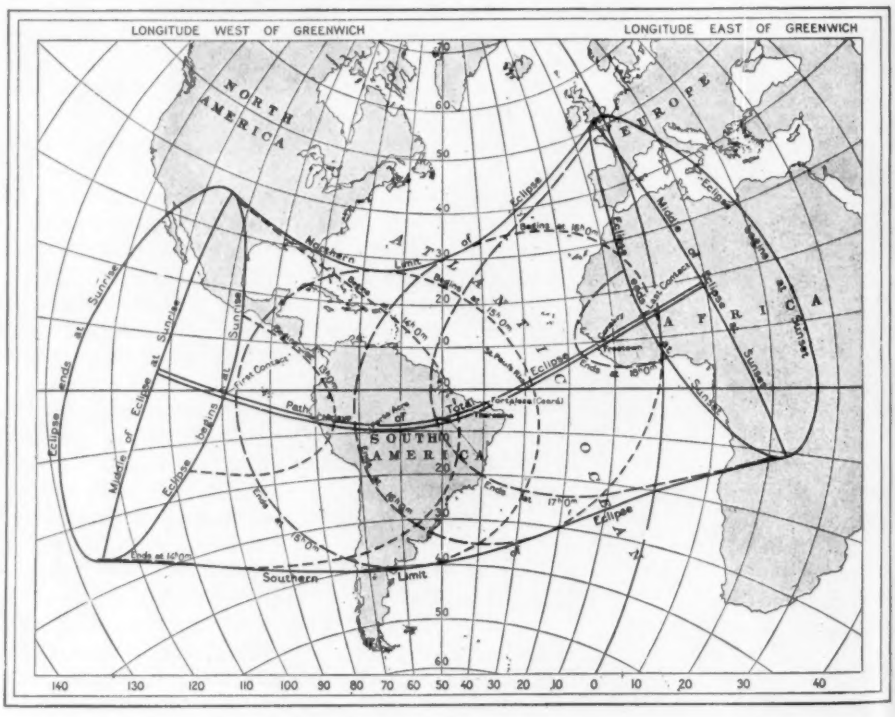
There is, however, good precedent for an astronomer to leave his country at war while he goes to observe an eclipse. In December, 1870, the French astronomer, Janssen, finding himself confined to Paris by the German siege, loaded the parts of a reflecting telescope into a balloon, climbed aboard and, with an assistant, floated over the German army. He almost came to grief through being carried out over the ocean; he finally landed near the mouth of the Loire River. He then traveled to Oran in North Africa, to observe the total solar eclipse of December 22, 1870, only to have clouds spoil his observations.

More recently, Russian and Chinese astronomers have found time to observe eclipses even though their countries were in the midst of the present war. Fortunately, astronomers from Central and South America will undoubtedly make a special effort to observe this eclipse.

If one must stay at home, one may look at maps and read descriptions of the eclipse territory, and plan what one will do if a sudden "break" permits the observation of the eclipse. Should one go to western Africa or to South America? In Africa, the maximum duration of totality will be only about 134 seconds and the altitude of the sun only about 25 degrees. One should plan to go to South America, then, unless conditions there appear to render satisfactory observations impossible.

On the map of the northern part of South America is shown the path of totality. The small rectangles outline the area covered by the other two maps. These in turn show in some detail the two regions which are relatively accessible, northern Peru and northeastern Brazil. The region in Brazil between Therezina and Fortaleza is only a few hundred feet above sea level, and since January is in the rainy season, the prospects for clear skies there are not very good. In Peru, the duration of totality is about a minute less than in Brazil, and the sun will be some 30 degrees lower in the sky. However, the prospects for clear skies are so much better

TOTAL ECLIPSE OF 25 JANUARY 1944



This chart, reproduced from the American Ephemeris and Nautical Almanac, shows that the eclipse will appear as partial in the southern United States. The hours of beginning and ending are in Universal or Greenwich civil time.

JANUARY 25, 1944

in the almost rainless desert west of the Andes that most astronomers would probably choose to go there.

The author has had the good fortune to travel in both regions, in northern Peru for the total eclipse of June 8, 1937, and in northeastern Brazil for that of October 1, 1940. Both regions are "civilized," and afford accommodations approximating those in similar regions in the United States. (One would not expect a Boston hotel in the middle of a desert!) The friendly cooperation of Peruvian and Brazilian scientists in our scientific work is the source of many pleasant memories. The majestic grandeur of the White Andes, and particularly of Mt. Huascaran and of the Callejon de Huaylas, cannot be exaggerated. Nor can justice be done in a few words to the beauty of the Brazilian pau d'arca in bloom and the tropical charm of Recife. Fortunately, those qualities are enduring and may be enjoyed later by travelers; it is only observation of the eclipse which will be frustrated by the war.

So that the reader can decide for himself where he would go if circumstances allowed, and for South American readers, a small table is given covering some of the principal points in the path of totality in the two regions mapped. The data for the Curú River are for a point about 30 miles west of Fortaleza (latitude 3° 40′ S., longitude 38° 59′ W.). The author is hoping that some of his good friends in these regions will observe the eclipse for him.

The one problem which is of the greatest interest at the present is this: Can the zodiacal light in the vicinity of the sun be seen and photographed during totality? Photographs made by our Schmidt camera in June, 1937, at Callan, Peru, 14,000 feet above sea level in the Black Andes, indicated that one *can* photograph the zodiacal light in the neighborhood of the sun under favorable conditions. It is necessary greatly to overexpose on the inner corona in order to record the phenomenon.

Visual observations made by Langley and Newcomb at the eclipse of July 29, 1878, and more recently by Honda at Hokkaido on June 19, 1936, suggest that under favorable conditions the zodiacal light may be seen near the sun during a total solar eclipse. Honda took the trouble to cover his head with a black bag for some time before totality, and during totality to blot out the inner corona and prominences with a properly placed disk. Thus his eyes were fully sensitive to the delicate gradations of light and shadow around the sun.

The visual observations may be undertaken by any person who will be in the path of totality and who is willing to forego a view of the inner corona and prominences, and who has a friend who will watch the progress of the eclipse through a dark glass and tell him when totality has arrived. If unusually long streamers are noted, the angle they make with the vertical should be measured and a sketch made as soon as possible after totality is over.

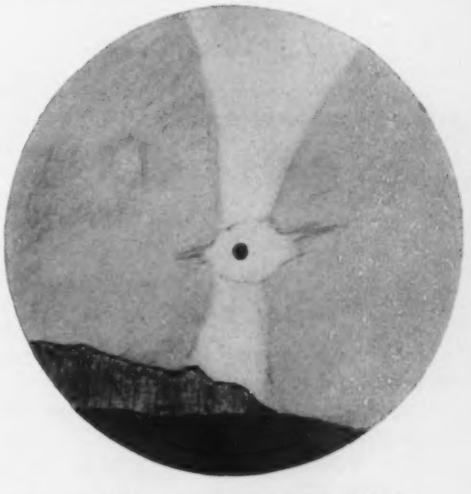
If fate were kind enough to provide a means of transportation to the eclipse and back, there is another problem we would like to work on, in the tropical skies after sunset and before sunrise. How bright is the zodiacal light at various distances from the sun? We have a new General Electric low-brightness meter which we would like to use on this problem. Measures have been made, especially by New Zealand amateur astronomers, but these have shown a wide variation. In some cases, the calibration of the meter used was open to question. To date, our new meter has been used on blacked-out city skies and on country skies in the dark of the moon.

There will be another total eclipse of the sun visible in South America and north Africa on May 20, 1947. Its path of totality will strike South America near Santiago, Chile, move northeastward and leave the continent near Bahia, Brazil. In Africa, it will travel near the equator, and the eclipse will end near the eastern coast. The maximum duration of totality on land will be about four minutes, 35 seconds, for a point near Bahia. As in the coming eclipse, the sun will be higher and totality will last longer in Brazil than in Africa.

If war makes the eclipse of January 25, 1944, impossible for us, as clouds spoiled our last one in 1940, we shall look ahead to 1947 and hope. While life last, there will be eclipses.

Place	Totality, G. C. T. Beginning	End	Duration	Sun's altitude at mid-totality
Chiclayo, Peru	14:07:23	14:10:10	167 sec.	39° 08′
Cajamarca, Peru	14:09:54	14:12:46	172	41 15
Therezina, Brazil	15:48:42	15:52:35	234	71 47
Ipú, Brazil	15:55:22	15:59:13	231	68 06
Curú, Brazil	16:00:37	16:04:26	229	66 44
Fortaleza, Brazil	16:01:59	16:05:27	207	65 37

The data for Chiclayo, Peru, except for the sun's altitude, were taken from the *American Ephemeris and Nautical Almanac* for 1944. The data for other positions were computed using the figures given in the *British Nautical Almanac* for 1944; they were checked by duplicate computation by Mr. Hervey Gauvin.



This sketch was made from photographs taken by the author with a Schmidt camera at the total solar eclipse of June 8, 1937. The double wedge of light extending above and below the sun may be of nature similar to the zodiacal light. Two mountain ranges are to be seen in the picture.

NEWS NOTES

By Dorrit Hoffleit

MORE ASTRONOMY IN SCOTLAND

The Royal Society of Edinburgh is the recipient of £30,000, the bequest of the late Robert Cormack of Edinburgh. This gift is for the purpose of promoting astronomical knowledge and research in Scotland, especially along lines set forth in a memorandum by the late Astronomer Royal of Scotland, R. A. Sampson. The available funds will be devoted to research fellowships, publication of research results, lectureships, purchase of instruments, and the popularization of astronomy. A large part of these plans cannot, however, be developed until after the war.

NEW TYPE MOUNTING

"That a great industrial concern may be interested in 'pure' science, of the 'useless' variety, no less than in immediate practical applications, is evidenced by the fact that General Electric is also assignee of another patent having little apparent connection with electricity."

This is how Science Service comments on the invention by Harold F. Morse, of Southport, Conn., of a new design for mountings for large astronomical telescopes. The design incorporates some of the elements of mounts of coast-defense guns. The tube is suspended on trunnions from massive supports that stand on a massive ring, bringing the instrument to bear in any direction. Two training arcs under the tube control the elevation of the telescope. Rotation of the tube, inherent in the mechanism, is compensated by rotation of the plate holder.

RED STARS

For the past several years, Dr. Oliver J. Lee and his associates at the Dearborn Observatory of Northwestern University have been conducting an intensive search for red stars. They have been interested particularly in the so-called *M* stars, which show conspicuous bands of titanium oxide in their spectra. The recently published *Dearborn Catalogue of Faint Red Stars,* by Lee, Baldwin, and Hamlin, lists 8,151 stars in the zone between declinations $-4°.5$ and $+22°.5$ and mainly from 9th to 11th apparent magnitudes. Only about one fifth of these stars had previously been known as *M*-type stars.

From representative counts of the percentages of these red stars relative to the total numbers of observable stars in the various areas, the authors find a variation from 1.7 per cent to 11 per cent, the largest percentage being in the Scorpius-Sagittarius region, in the direction of the center of our galactic system.

In their discussion of the material, the authors comment that evidence so far seems to indicate that, among the redder of these *M* stars, dwarfs are relatively rare and giants relatively numerous in our vicinity.

DISCOVERED: RECORD BOOKS

A recent publication from Stockholm reports on the discovery of old record books kept by the 18th-century Swedish astronomer, Peter Wargentin. They contain valuable observations of Mira Ceti in the years 1751-1782. These observations are the most extensive available for such an early epoch. Happily they cover the brightest maximum ever observed for that much-examined variable star.

Mira has a period of over 330 days. Individual cycles differ considerably in amplitude, the usually quoted extremes of brightness being magnitudes 2.0 and 10.1. The newly discovered old observations show that Mira attained magnitude 1.2 on November 11-12, 1779—about twice the brightness of its more recent maxima.

MOUNT WILSON ANNUAL REPORT

The recently published annual report of the director of the Mount Wilson Observatory (Dr. Walter S. Adams) summarizes an impressive amount of astronomical research completed during the year 1941-1942. Much of the time of the staff had necessarily been diverted from astronomy to the war effort. Nevertheless, the observatory's bibliography for that year contains well over 60 research papers. They include extensive investigations of the sun, stellar spectroscopy, studies of galactic nebulosities and external galaxies, including supernovae. On numerous of these investigations we have already reported as results were published (for example, the identification of Kepler's nova, the Crab nebula, and the supernova of 1054; interstellar material; the direction of rotation in spiral nebulae).

Awaited by solar physicists is a table of approximately 7,500 lines observed in the infrared spectrum of the sun (6600 angstroms to 13500) being prepared by H. D. Babcock, of Mount Wilson, and Charlotte Moore Sitterly, of Princeton University Observatory. About half of the lines observed originate in the earth's atmosphere, through which sunlight must necessarily pass before it can be analyzed. About a quarter of the lines involved are known to be of solar origin.

In the course of the determination of stellar distances, more than 130 stars fainter than 10th absolute magnitude (about 100 times less luminous than the sun) have been found by A. van Maanen since 1913, when less than two dozen such dwarf stars were known.

SOUTH AFRICAN AMATEUR DIES

George Edmund Ensor, the leading amateur astronomer in Pretoria, South Africa, died on June 9th, at the age of 70. In a letter to Leon Campbell, recorder of the A.A.V.S.O. (for which Ensor made several thousand variable star observations over the period from March, 1926, to July, 1940), H. E. Houghton, also of Pretoria, tells of having seen his fellow amateur in church the preceding Sunday, apparently in good health.

Ensor was a New Zealander, but lived in South Africa for 40 years. He was best known as the radiographer at the General Hospital, and was expert at electrical and photographic work.

His variable star observations were made mostly with a 6½-inch reflector, which he also used for occulation work. Ensor discovered a comet in 1925, and shared with Houghton the discovery of another in 1932.

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ASTRONOMICAL ANECDOTES

THE MOST DIFFICULT SATELLITES OF URANUS

IN 1787, Sir William Herschel had discovered Titania and Oberon, the outer satellites of Uranus, and had remarked on the peculiar orientation of their orbits—almost perpendicular to the ecliptic. He thought he had also found four other satellites of Uranus, and in many old books one finds it stated that the planet is accompanied by a retinue of six.

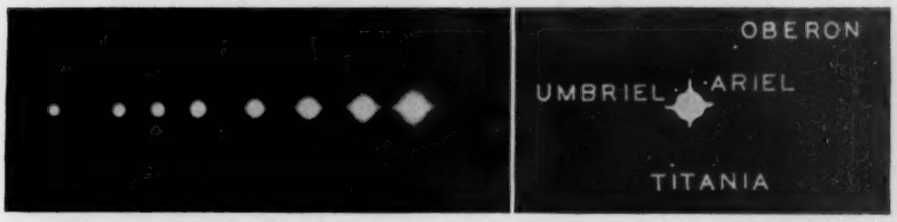
But it remained for William Lassell, in this month of the year 1851, to discover what have been called the "most difficult satellites of the solar system." Says Young, "They are telescopically the smallest bodies in the solar system, and the most difficult to see," but this was before the discovery of Jupiter *V*.

I've not seen them, but now I'm going to look, and test how little aperture is needed to see them. For there appears to be good reason to doubt their extreme faintness as usually given. The magnitudes commonly cited are those due to Newcomb (for Ariel and Umbriel); Vogel gave the magnitudes for the outer satellites. But last year Dr. W. H. Steavenson, of the British Astronomical Association, questioned these traditional values, and suggested revised ones. From current textbooks and handbooks, the material of the following table has been collected; in the last column are the values of the magnitudes suggested by Dr. Steavenson. Of course, changes in magnitude will produce changes in the accepted diameters.

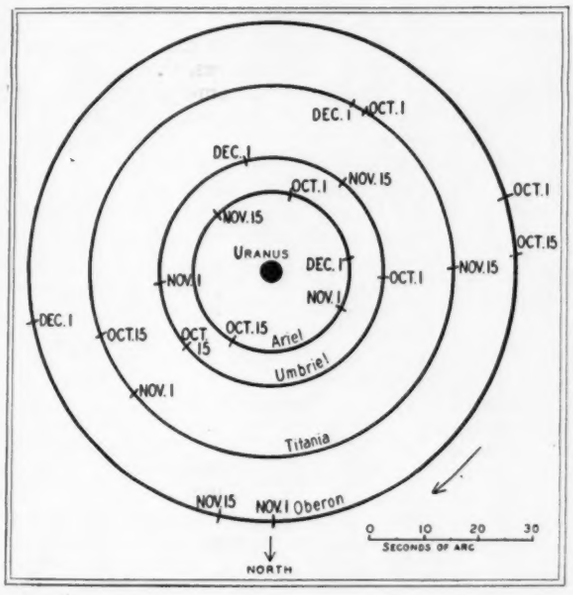
In 1876, a Mr. Isaac W. Ward, of Belfast (who sometimes wrote under the name "Linea"), saw Titania and Oberon with a telescope of only 4.3 inches aperture, but he is known to have had phenomenal eyesight. These two outer satellites are comparatively easy with a good 8-inch, backed up by a good eye.

But the inner ones are much more difficult, and most observers seem to agree that Ariel almost always demands that Uranus itself be hidden behind a bar in the eyepiece, even with a 12-inch or larger.

During these next few years, those who wish to try their eyes and instruments have an excellent opportunity to do so, for the satellites are, in a way of speaking, constantly in elongation, inasmuch as we now see their orbits spread out like the rings of a target. The maximum condition is not due until 1945, but there will be but little change during the next four or five years. In 1966 we shall see the orbits edge on; the satellites will appear to travel on a straight line, and the great oblateness of the planet will be most noticeable.



The four satellites of Uranus, as they appeared on September 18, 1931. Enlarged 10 times from the original negative, the picture shows a multiple series of images of Uranus, with exposures increasing from one second to 96 seconds, with south at the top. Positions of the satellites in the last image are shown in the diagram on the right. The planet, hundreds of times as bright as any of the satellites, is very much overexposed on the photograph — the least exposed of the series is the only one that furnishes a more or less normal picture of the planet itself. The photograph and identification of the satellites are by courtesy of Lick Observatory.



The positions of the satellites are shown for 8 p.m. E.W.T., on October 1 and 15, November 1 and 15, and December 1, 1943. Determine the number of days and hours counting ahead from one of these dates and times to the date and time of your observation. Multiply the number of days by the "motion per day" given below; multiply the number of hours by the "motion per hour"; and add these results, rejecting multiples of 360° if necessary. The final result will be the number of degrees, clockwise from the chosen position, at which the satellite in question will be found.

Satellite	Period	Motion per day	Motion per hr.
Ariel	2d 12h.5	142°.80	5°.95
Umbriel	4d 03h.5	86°.83	3°.62
Titania	8d 16h.9	41°.36	1°.72
Oberon	13d 11h.1	26°.74	1°.11

Satellite	Magnitude	Diameter (miles)	Distance (miles)	Elongation	Steavenson magnitude
Ariel	16	500	119,000	14″	13.7
Umbriel	16-17	400	166,000	20″	14.5
Titania	14	1,000	272,000	33″	13.5
Oberon	14	900	364,000	44″	13.7

In the favorable situation which now prevails, one doesn't have to wait for a particular hour of a particular night to make sure that a given satellite will not be hidden by the planet itself or by its glare. But it is still helpful to know the direction from the planet in which the satellite will be found. In the accompanying diagram, the proper relative sizes of the planet and the orbits of the satellites are shown. By means of the instructions given in the caption, and the data in the table, it should be possible for an observer to locate the satellites in their proper relative positions, for any time desired during the next two months at least.

Of course, it is necessary first to locate the planet itself, but it is presumed here that anyone who has an instrument capable of showing the satellites will know how and where to find the planet, whose opposition occurs November 29th this year. [See the sketch map on page 20.] The magnitude at opposition will be 5.9; try to see Uranus with the naked eye. I shall be very glad to hear how many people find the satellites, and the details of the observations: size, type, and make of telescope, magnifying power, seeing conditions, relative brightnesses of the satellites, and so forth. Good hunting!

R. K. M.

The Harvard Books on Astronomy

Edited By Harlow Shapley and Bart J. Bok

Harvard College Observatory

ATOMS, STARS AND NEBULAE

This is the latest volume in the Harvard Series. It probes into the atmospheres of stars and even digs into their interiors. 150 Illus. 323 Pages. $2.50. (1943) By *L. Goldberg* and *L. H. Aller.*

BETWEEN THE PLANETS

It summarizes our knowledge of comets, meteors, asteroids and meteorites, describes the latest discoveries and considers problems yet unexplained. 106 Illus. 222 Pages. $2.50. (1941) By *F. G. Watson.*

EARTH, MOON AND PLANETS

A concise, well illustrated account of the planets and their atmospheres. A discussion of the possibilities of life outside the earth, and a planet finder and star chart, are included. 140 Illus. 293 Pages. $2.50. (1941) By *F. L. Whipple.*

THE MILKY WAY

The dust and gas between the stars, star clusters, the appearance of our own galaxy to an observer in the Andromeda nebula and the problems related to the past and future of our galaxy are discussed. Large scale photographic maps are included. 96 Illus. 204 Pages. $2.50. (1941) By *Bart J. Bok* and *Priscilla F. Bok.*

THE STORY OF VARIABLE STARS

This book introduces the reader to the technique of observations and then analyzes the present state of our knowledge of variable stars. Lists of variables, a Julian calendar, and other tables are included. 82 Illus. 226 Pages. $2.50. (1941) By *L. Campbell* and *L. Jacchia.*

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BOOKS AND THE SKY

J. J. THOMSON

Lord Rayleigh. The University Press, Cambridge; The Macmillan Company, New York, 1943. 299 pages. $6.00.

THE autobiography, **Recollections and Reflections**, written by J. J. Thomson, has already helped many readers to understand the personality and achievements of a great physicist and a great man. "When it was suggested to me by his family that I might attempt a biography," says Lord Rayleigh in the preface to **J. J. Thomson**, "I was inclined to take the view that the subject was almost exhausted. However, on further consideration, it seemed that there was room for a different treatment of his life." As a result of this point of view, the author has produced a most enjoyable book supplementing Thomson's autobiography.

The life of J. J., as he was familiarly called by all who knew him well, may be divided into two fairly distinct parts. The first of these was as a student, professor, and experimental physicist. The second part of his career began about the time of World War I, when J. J. was elected president of the Royal Society, engaged in scientific activities connected with the war, and finally became master of Trinity College. During this latter 25 years, administrative duties took more and more of his time, and he did little or no scientific work.

Thomson began his investigations in experimental physics at the Cavendish Laboratory, Trinity College, under the third Lord Rayleigh, father of J. J.'s biographer. His first research, the determination of the ratio of the electromagnetic to the electrostatic unit of electrical quantity, was neither novel nor startling. But it must have shown him to be a good worker, for when Lord Rayleigh resigned, J. J. was appointed Cavendish professor in his place. Thus began Thomson's rise to one of the foremost positions in the field of experimental physics.

At about this time, in 1884, Thomson began to experiment on electric discharge, probably with the instinctive feeling that here was the field which really offered a hope of penetrating the secret of the nature of electricity and its relation to matter. The great turning point at which his work reached a high level, however, was the discovery of X-rays by Roentgen in 1896. J. J., in his experiments with X-rays, soon found that the rays caused the discharge of an electroscope. That is, while air under ordinary conditions is a non-conductor of electricity, air in the beam of X-rays becomes a conductor.

When a wire conducts electricity, the case which is familiar to us all, the current which passes is proportional to the electromotive force applied. If we double the voltage, we double the current, provided the wire does not get hot and thus change its characteristics. When J. J. measured current passed by the air between two electrified plates exposed to X-rays, he found that "at first it increased proportionately to the electromotive force, but then more slowly, until finally a stage was reached when it was independent of any further increase in the electromotive force."

At this point in his research, Thomson invited Rutherford, one of his most promising students at the Cavendish Laboratory, to join him, and in an epoch-making investigation they together worked out many of the properties of the conducting gas. They found: (1) "That the conducting power of the air persisted for a second or two after it had been blown away from the direct path of the rays, but that it soon reverted to the non-conducting state if left to itself." (2) "The process of carrying a current deprived the air of its conductivity."

The exact method of the formation of the ions (carriers of the current) was not known at that time, but it seemed logical that the X-rays must form equal numbers of both positive and negative ions by somehow breaking up the air molecules. When left to themselves, these ions would join or coalesce in some manner to form ordinary air particles once more.

The process of carrying a current is thus easily seen. The negative ions are attracted to the positive plate; the positive ions, to the negative plate, and the motions of the ions constitute an electric current. During their progress toward a charged plate, they may recombine, but the X-rays form new ions to again take up the current. As the electromotive force is increased, the velocity of the ions between the plates is increased, and the opportunity for recombination is decreased. With continued increase in electromotive force, there must be some point reached where the velocity of all the ions is so great that there is almost no opportunity to recombine during the period of travel between the plates. Thus all the ions are in use, and the current is "saturated." This reasoning led to the paradoxical result that moving the plates apart should give more current, since then more ions would be available. The prediction was verified and served as a

NEW BOOKS RECEIVED

SOLAR RELATIONS TO WEATHER, *Henry Helm Clayton*, 1943, *Clayton Weather Service*, 1410 Washington St., Canton, Mass. Vol. I, 105 pages, $3.00; Vol. II, 439 pages, $3.00.

In Vol. I of this set, the influence of solar variations on the weather, and on life, and the possible origin of the variations, are discussed. Vol. II gives reprints of the original papers, the results of which have been incorporated into the first volume.

THE ASTRONOMICAL TABLES OF THE MAYA, *Maud Worcester Makemson*, 1943, in Carnegie Institution of Washington *Publication* 546, pages 183-221.

A scholarly discussion of the Maya eclipse calendar in relation to our Julian calendar; of the Mayan tables of Venus; and of the positions of the equinoxes and solstices in the Maya calendar.

check on the work of Thomson and Rutherford.

This short review of some of Thomson's earlier work will perhaps show that this book is somewhat technical. While no mathematical formulae are used, the book is not one which should be read hastily if the reader does not have some knowledge of physics, particularly of the discharge of electricity through gases, and the principles involved in deflection of charged particles in electric and magnetic fields. With a basic knowledge of these subjects, however, one should find the book most interesting.

In addition to the section describing the experiment mentioned above, there are sections dealing with the first evaluation of **e/m**, the first ideas on the existence of the electron, work on positive rays, the first detection of isotopes outside the field of radioactive research, and so forth. But it should not be thought that the biography deals only with scientific discoveries, for in reading it one learns to know J. J. not only as a physicist, but as a man. There are many choice stories about J. J.

On one occasion, Everett, J. J.'s assistant, "had very carefully made several small thin metal discs of different metals but all of the same diameter and weight. J. J. was talking to him about the experiment for which the discs were required, and he picked them up one by one and rolled them into little balls. Then he put them down and walked away quite happily. Poor Everett began making a fresh start."

And again, J. J. was attempting to reflect, by means of a magnetic field, positive rays produced in a glass globe some six inches in diameter, situated between the poles of a large Du Bois electromagnet. J. J. had his eye to a microscope and was observing the motion of the gold leaf of an electroscope across a scale. The conversation was overheard.

"J. J. 'Put the magnet on.' Then followed a click as Everett closed a large switch.

"J. J. 'Put the magnet on.'

"Everett. 'It is on.'

"J. J. (eye still to the microscope). 'No, it isn't on. Put it on.'

"Everett. 'It is on.'

"A moment later J. J. called for a compass needle. Everett went out of the room and returned with a large needle, 10 inches long, which was used in elementary lectures in magnetism. J. J. took it and approached the electromagnet. When about a foot away, the needle was so strongly attracted by the electromagnet that it swung around and flew off its pivot, crashing into the bulb (which burst with a loud report) and coming to rest between the poles of the magnet. The spectators looked up to see what had happened. Everett was glowing with triumph, and J. J. looking at the wreck with an air of dejection. 'Hm,' he said. 'It was on.'

"There are three eye witnesses to this incident. The variations between them are trifling."

The honors and distinctions received by Thomson for his remarkable work in physics were, of course, very numerous. Foremost of these was the Nobel prize in 1906.

The later chapters in Lord Rayleigh's book deal with Thomson's views on education, his trips to America, administrative duties as master of Trinity, and the closing years of his remarkable life.

J. J. Thomson is a book well worth reading for anyone interested in the life of a great man and a great physicist, a life which, as J. J. says in **Recollections and Reflections**, extended from a time when "there were no bicycles, no motor cars, no aeroplanes, no telephones, no wireless, no gramophones, no electrical engineering, no X-ray photographs, no cinemas, no germs, at least none recognized by the doctors," up to the present decade.

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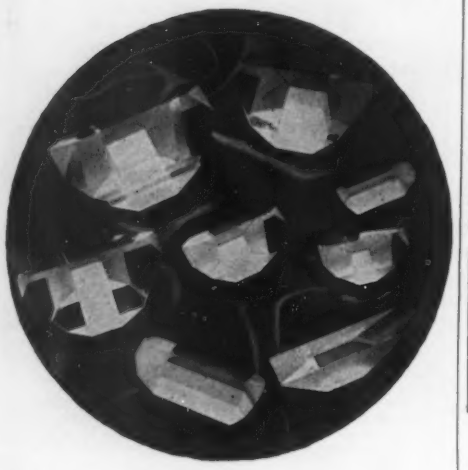

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GLEANINGS FOR A. T. M.s

Designing an Achromatic Objective—VIII

(Concluded from the August and previous issues)

19. Transfer Equations. Since we are now measuring distances *along the chief ray*, we cannot merely subtract the axial thickness d to obtain the opening intersection-length for the next succeeding surface.

We have to determine the distance $P_jP_{j+1} = D'j$; where the axial thickness, $A_jA_{j+1} = d'_j$ (Figure 16).

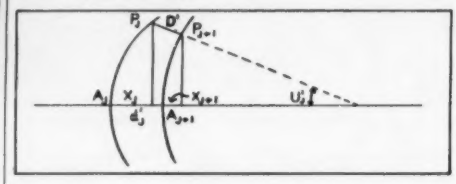

Figure 16.

The distance is, from inspection: $D'_j = (d'_j + X_{j+1} - X_j)/\cos U'_j$.

Now (Figure 17) $X_j = AC - RC = r - r\cos(U+I) = r[1 - \cos(U+I)]$. But, from trigonometry, we have $1 - \cos x = 2\sin^2 1/2\,x$, therefore, $X_j = 2r\sin^2 1/2\,(U + I)$.

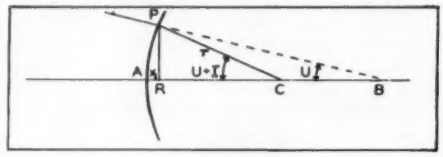

Figure 17.

20. The Computations for Astigmatism. We can now proceed with our computation of astigmatism, which is shown in Table X. (Table XI contains the computations of the opening t and s for each successive surface, according to the equations worked out in Section 19.)

The astigmatism ($l'_s - l'_t$) comes out .008″ (Table XI), which is well within the tolerance of .121″ given in Section 15.

21. Conclusion. Our lens is now complete and ready for the workbench, with specifications as follows:

Crown: Diameter, 6″; thickness, .780″; $r_1 = 53.100''$; $r_2 = -30.177''$; LBC-2 with N_d, 1.57250; N_f, 1.57953; N_c, 1.56956.

Flint: Diameter, 6″; thickness, .500″; $r_1 = -30.177''$; $r_2 = -365.000''$; DF-2 with N_d, 1.61700; N_f, 1.62904; N_c, 1.61218.

And with the following optical characteristics:

Equivalent focal length	f = y/u′	90.989″
Back focus	l′	90.249″
Axial spherical aberration	l′—L′	—.005″
Axial chromatic aberration	$l'_c - l'_f$	+.006″
Curvature of field		—.040″
Coma		—.002″
Distortion		+.001″
Astigmatism		+.008″

We have not investigated the spherical or chromatic aberration for oblique pencils, nor have we made a complete study of coma, but the above results indicate that the lens will be quite satisfactory if we do not insist upon special optical properties.

Also, we have designed the above objective without reference to the eyepiece or eyepieces with which it is to be used, and also without consideration of the chromatic faults of the eye. It is customary to overcorrect objectives, that is, to introduce negative chromatic aberration, purposely to compensate for an undercorrection (positive chromatic aberration) in the eyepiece, and also to compensate for the chromatic errors of the eye, which is not, as is often erroneously thought, an achromatic optical device. The problem of eyepieces is a separate and complex one which we have no space for in this series of articles, but the subject may be discussed at some length in the near future.

An extremely important point to be noticed here is that all the equations which we have developed regarding all the properties of the lens were discussed without any regard to units of measurement. Although we talked in inches, and computed a lens six inches in diameter with a focal length of 90 inches, if we had computed a lens six centimeters in diameter with a focal length of 90 centimeters, we would have arrived at exactly the same numerical results as we did reach, except that they

TABLE X

EQUATIONS FOR ASTIGMATISM

	Surface 1	Surface 2	Surface 3
log N′	0.19659	0.20871	0.00000
+log cos I'_c	9.99999	9.99999	9.99998
log N′ cos I'_c	0.19658	0.20870	9.99998
-log r	1.72509	1.47968n	2.56229n
log B	8.47149	8.72902n	7.43769n
B	.02961	-.05358	-.00274
log N	0.00000	0.19659	0.20871
+log cos I_c	9.99998	9.99999	9.99999
log N cos I_c	9.99998	0.19658	0.20870
-log r	1.72509	1.47968n	2.56229n
log C	8.27489	8.71690n	7.64641n
C	.01883	-.05211	-.00443
log N	0.00000	0.19659	0.20871
+2 log cos I_c	9.99996	9.99999	9.99999
log N cos^2 I_c	9.99996	0.19658	0.20870
-log t	inf.	2.16164	2.23571
log D	-inf.	8.03494	7.97299
D	0	.01084	.00940
log N	0.00000	0.19659	0.20871
-log s	inf.	2.16166	2.23572
log E	-inf.	8.03493	7.97299
E	0	.01084	.00940
log N′	0.19659	0.20871	0.00000
+2 log cos I'_c	9.99998	9.99999	9.99996
log F	0.19657	0.20870	9.99996
B	.02961	-.05358	-.00274
+D	0	+.01084	+.00940
-C	-.01883	+.05211	+.00443
G	.01078	.00937	.01109
B	.02961	-.05358	-.00274
+E	0	+.01084	+.00940
-C	-.01883	+.05211	+.00443
H	.01078	.00937	.01109
log F	0.19657	0.20870	9.99996
-log G	8.03262	7.97174	8.04493
log t′	2.16395	2.23696	1.95503
t′	145.8650	172.5680	90.1633
-D′	-.7753	-.4976	
t_1	145.0897	172.0704	
log N′	0.19659	0.20871	0.00000
-log H	8.03262	7.97174	8.04493
log s′	2.16397	2.23697	1.95507
s′	145.8710	172.5720	90.1716
-D′	-.7753	-.4976	
s_1	145.0957	172.0744	

would then represent centimeters. Consequently, the above lens computation is not restricted to a lens of 6-inch diameter, but may be applied with equal facility to a lens of 3-inch diameter, or any other size. To do this, it is only necessary to reduce all the radii in the same proportion. The focal length will, of course, be reduced in the same way, and also the aberrations will be equally reduced. Thus, for a 3-inch lens, we would have:

Crown: Diameter, 3″; thickness, .390″; $r_1 = 26.550''$; $r_2 = -15.0885''$;

Flint: Diameter, 3″; thickness, .250″; $r_3 = -15.0885''$; $r_4 = -182.500''$; with focal length and all aberrations reduced by one half.

TABLE XI

TRANSFER EQUATIONS

	Surface 1	Surface 2	Surface 3
U_c	0°32'00"	0-20-21	0-19-49
$+I_c$	-0-32-00	-0-19-41	-0-19-45
$U_c + I_c$	0-00-00	0-00-32	0-00-04
log sin $1/2(U_c+I_c)$	-inf.	5.88969	4.98660
+log 2r	-	1.78071n	2.86332n
log X_c	-inf.	7.67040n	7.84992n
X_c	0	-.00468	-.00708
d'	.7800	.5000	-
$+X_{cj}+1$	-.0047	-.0071	-
$-X_{cj}$	0	+.0047	-
R	.7753	.4976	-
log R	9.88947	9.69688	-
-log cos U'_c	9.99999	9.99999	-
log D'_j	9.88948	9.69689	-
D'_j	.7753	.4976	-

Astigmatism			
log t'	1.95503	log s'	1.95507
+log cos U'_c	9.99998	+ log cos U'_c	9.99998
log t' cos U'_c	1.95501	log s' cos U'_c	1.95505
t' cos U'_c	90.1692	s' cos U'_c	90.1675
$+X_c$	-.0071	$+X_c$	-.0071
$1'_t$	90.162	$1'_s$	90.160
		Astigmatism: $1'_s - 1'_t$	+.008

Let us summarize briefly our procedure in computation:

1. Decide upon diameter and focal length. Any convenient figures will do, so long as they are in the proper ratio and represent the maximum dimensions likely to be required, for we can change everything proportionally later on.

2. Select the glass and compute preliminary radii of curvature. The condition for achromatism, together with one other arbitrary value (in our case we chose for this arbitrary value: that the back surface of the flint should be plane), will give us all the three radii (assuming a cemented lens).

3. Choose the axial thickness of the components, which should not be less than 1/12 the diameter for a concave lens, and more for a convex lens.

4. Trace a paraxial ray for N_d, N_c, and N_f, and a marginal ray at the extreme margin for N_d, to determine preliminary chromatic and spherical aberrations.

5. If the aberrations are beyond the tolerances, and they will almost surely be, make two adjustments to the radius of a selected surface (in our case, the rear of the flint), one adjustment being to a steeper curve, the other to a flatter curve, and compute the same four rays for each of these adjustments.

6. Plot on a graph the resulting figures for chromatic aberration against the curvature of the selected surface, and determine at what curvature the chromatic aberration will be zero. (Two of the plotted points should differ in sign.)

7. Compute the same four rays for this value of the curvature and verify the result for chromatic aberration; also, investigate the spherical aberration for this value. If the spherical aberration is still beyond the tolerance, go back and adjust other surfaces until it is disposed of without introducing chromatic aberration again. We were fortunate—in most cases this part of the work may be very tedious.

8 Trace one central and two marginal oblique rays at the extreme limit of the field of view and determine therefrom curvature of the field, coma, and distortion.

9. Compute astigmatism by the special equations, using the data of the chief ray traced in Section **8.** In astronomical objectives, due to the restricted field of view and the long focal length, it is extremely unlikely that any of the oblique aberrations will be objectionable, so that it is unnecessary to do more than to make sure of this by the procedures in Sections 8 and **9.** If we were professional optical designers, we should probably leave this part of the work out altogether, but it has been included here for the sake of completeness, and the novice should never leave it out.

We have been very arbitrary in our selection of glasses for our lens, a procedure justified only by the nature of our objective (small field of view, long focal length). If we had been designing a lens of considerable field of view, and/or in which we desired certain specific qualities, such as flatness of field or orthoscopy (freedom from distortion), the oblique aberrations would have given us no end of trouble unless we had selected glasses for the specific purpose of making our desired corrections possible. There are various mathematical relationships between the indices and dispersions of optical glass combinations and the magnitude of the oblique aberrations of an objective constructed of them.

Furthermore, we have (as we mentioned at the outset we would) taken the long way around. With the data of our first set of calculations, we could have developed equations for the aberrations which would have given us satisfactory approximate values and made actual ray tracing unnecessary. But we are not prepared, in these pages, to go into the extensive theoretical discussion necessary to develop such equations, nor, do we believe, are most of our readers willing to follow us through the deeper morasses of mathematics. We must leave those who desire to investigate the more theoretical phases of geometrical optics to delve into the treatises on this subject, of which we mention but two of the best:

Applied Optics and Optical Design, A. E. Conrady, Oxford University Press.

Mirrors, Prisms and Lenses, J. P. C. Southall, The Macmillan Company.

Gleanings for A.T.M.s is always open for comments, criticisms, and suggestions. We are here to serve, in every possible way, all the members of the telescope making fraternity—particularly in these days when a hobby may serve as welcome relief from the press of wartime duties.

SKY-GAZERS EXCHANGE

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THE STORY OF VV CEPHEI

(*Continued from page 5*)

servable factors will enable us to remove the pulsational velocities.

Second, the velocity of the *B* star has not been measured. It was at first supposed that the hydrogen absorption lines arose in the *B* star—a natural assumption, since the velocities were of the right size. But instead of crossing the *M* velocity curve near the time of eclipse, the velocities of these hydrogen lines remained constant, and, of course, could not be attributed to the *B* star. A search by the author and by Yerkes observers has to date failed to discover measurable lines attributable solely to the *B* star and compatible with our knowledge about its orbit. The result is that the ratio of the masses of the two stars has not yet been measured and must be deduced, with considerable uncertainty, from the stars' luminosities.

Third, the methods which have been used to discover the tilt of the orbit relative to the observer depend upon the assumption that the 22-day interval of increasing light as the *B* star emerges represents the time required for the disk of the *B* star to move from internal to external tangency with the disk of the *M* star, as seen from the earth. But the relative dimensions of this system are so extraordinary that a new possibility arises: the limb of the large, diffuse *M* star may not be a perfectly sharp line, and the gradual increase in light may be due to the diminishing opacity of this limb as the *B* star emerges, just as the sun gradually brightens as it rises above a hazy horizon. If this is the case, the inclination of the orbit becomes indeterminate, and it is upon the inclination that derivation of the dimensions of the two stars depends.

Putting this uncertainty aside for the moment, let us examine the results of the computation made in the customary way: the *B* star has a diameter of 19,000,000 miles, a mass of 40 times the sun's, and a density of 0.006 grams per cubic centimeter. The *M* star has the astonishing diameter of 2,500,000,000 miles, a mass of 57 suns, a density of 0.000,000,003, and a luminosity (in all wave lengths combined) of 250,000 times the sun's. The *M* star is 3,000 times the linear size of the sun, or 27 billion times its volume. If all of the other stars in our galaxy were of the same size as the sun, they would fit into a space not much more than that inside this monstrous star!

The density of this star is perhaps its most extraordinary feature. The density of air at the surface of the earth is 0.0012 grams per cubic centimeter; the density of the *M* supergiant is 1/400,000 as great. It would require a good vacuum pump to produce so low a density. The material in the star is undoubtedly very strongly concentrated toward its center, so that the upper regions of the star must have a vastly smaller density still.

If we reject the assumption of a sharp disk, then the *M* star may have any radius from 3,000 down to 1,200 times the sun's, and a density from 0.000,000,003 up to 0.000,000,04, the mass remaining nearly the same.

With these values it becomes possible to translate the dates at which the hydrogen lines reappear and the dates at which the absorption lines resume their normal intensities into relative heights above the surfaces of the two stars. These dimensions are shown in the upper drawing in Figure 2. Below this is shown the corresponding diagram representing the limiting case if we assume that the *M* disk is not sharp. Perhaps the truth lies somewhere between the two.

With the completion of the spectroscopic orbit, the role of the iron emission region becomes clear. Its radial velocity remains constant (although with secondary variations) at the center-of-mass velocity of the system. This emission region is therefore a region of nebulosity in which the entire binary system is embedded, but which occupies a very much larger space than the orbits of the stars. This view is strongly supported both by the eclipse phenomena and by the theoretical requirements for the production of forbidden lines.

At present the two big question marks in the system are the inclination and the mass ratio. Recently there has appeared evidence that a third may exist. The absolute magnitudes given by the study of the star as a binary system, when compared with the observed apparent magnitude, indicate that the system is from 1,000 to 2,500 parsecs (one parsec equals 3¼ light-years) from the earth. Dr. P. van de Kamp estimated that at this distance the angular dimensions of the system might be large enough to permit astrometric measurement of the orbit of the *M* star, and undertook observations of it at Sproul Observatory. Dr. Gustav Land has reported that the preliminary results of this program indicate an orbit of many times the expected angular size and a distance far less than is now regarded as probable. Perhaps the star is in some way less luminous than our computations indicate. Or perhaps the nebulosity enmeshing the system is extensive enough to be partly opaque, and dims the light coming from the star.

All of these questions are answerable, given enough time. The shape and orientation of the orbit are such that the time when the stars are most nearly in line with the earth is not midway between the time of entrance into and the time of emergence from eclipse. Furthermore, the displacement from this midpoint is greater, the smaller the inclination is presumed to be. After several cycles are observed, the spectroscopic orbit will be computed precisely enough so that the time of alignment will be accurately known, and the inclination will then be determined. The mass ratio will probably become known from radial velocity measurements of far ultraviolet lines, or possibly from direct observational astrometry of the *B* star through ultraviolet filters.

By the time these things have been accomplished (after several cycles of 20 years each!) we will have some very interesting information. The displacement of the hydrogen emission lines when half of the emission region is in eclipse will enable us to study its rotation and to decide the question of the correctness of our present rotating-pulsating model of *Be* variables. Changes in the duration of eclipse will have given us immediate information about the size of pulsations of the *photosphere* of the *M* star, to be compared with the pulsations observed in its *atmosphere* through radial velocities.

The long period of VV Cephei gives it a unique place among eclipsing binaries, but the men who want to study the eclipse would have been just as happy if the star did not have this particular distinction!

THE INDEX FOR VOLUME II

is in preparation. It will be similar to that for Volume I, including title page, author, title, subject, and topic references. The index adds considerably to the usefulness of the year's issues. Send 25c and we shall mail your copy as soon as it is off the press.

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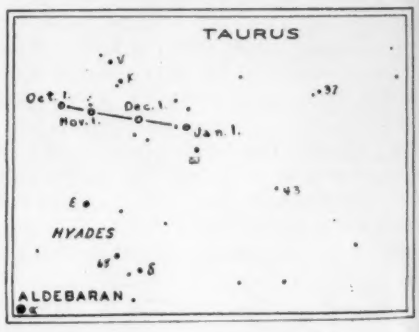
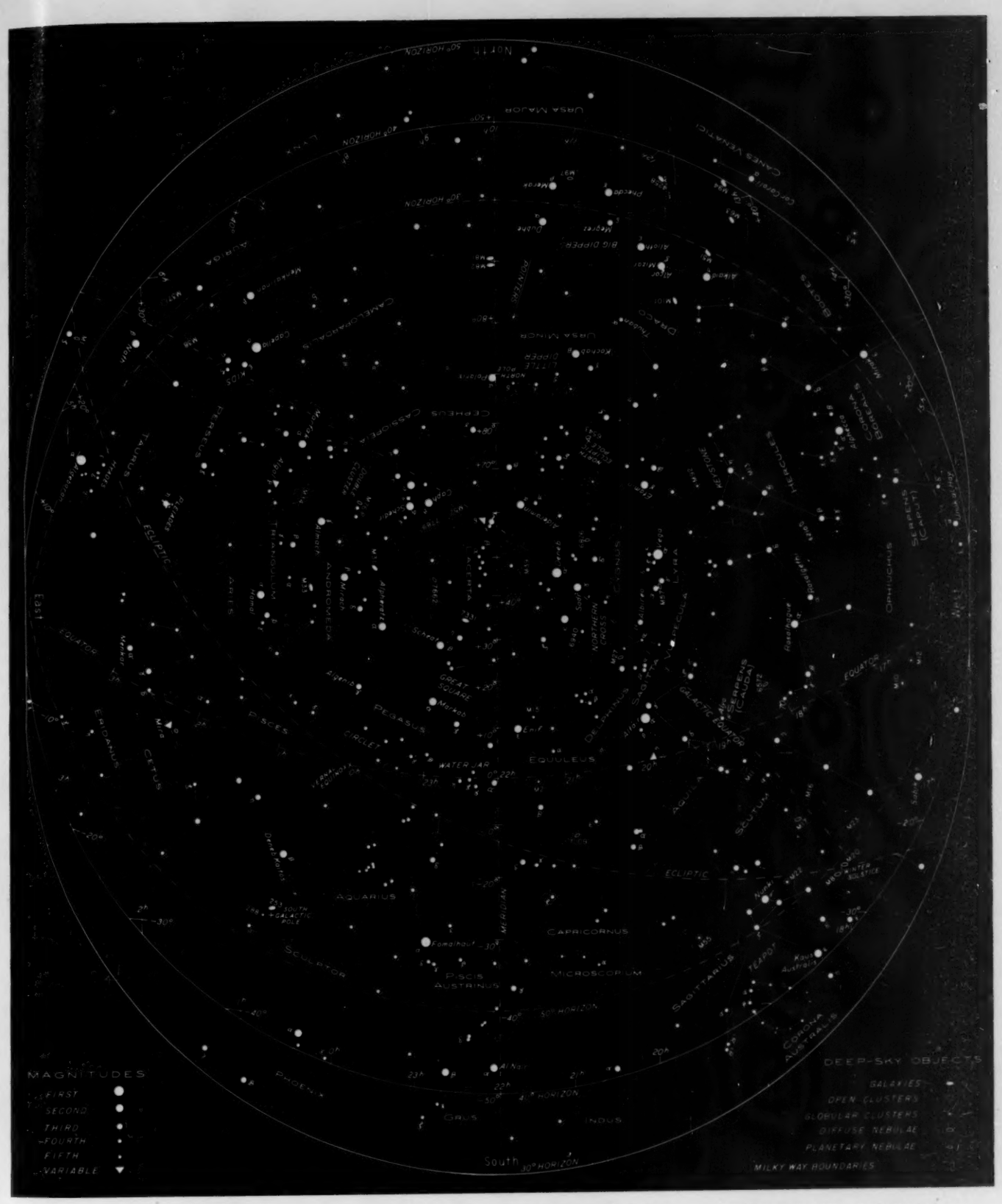
THE PATH OF URANUS



This chart shows the path of Uranus from October to January. Uranus is about twice as bright as the faintest star included here. See "Astronomical Anecdotes," page 15, for the story of Uranus' four satellites.



DEEP-SKY WONDERS

THIS month finds the following objects in good position for observation with moderate-sized telescopes. Descriptions are from Norton's **Star Atlas.**

Cassiopeia. M52, $23^h\ 22^m.0$, $+61°\ 19'$; an irregular cluster about 20′ in diameter, containing an orange star. N.G.C. 7789, $23^h\ 54^m.5$, $+56°\ 26'$; a large cluster of very faint stars.

Pegasus. M15, $21^h\ 27^m.6$, $+\ 11°\ 57'$; one of the best globular clusters, bright and condensed, 6′ in diameter.

Triangulum. M33, $1^h\ 31^m.0$, $+30°\ 24'$. This spiral nebula is visible to the naked eye, but its lack of compactness makes it a difficult object except under the best conditions for perfect eyesight. Low power shows it best as being large, ill-defined, with bright, irregular, central portions. It is considered to be as close to us as the Great nebula in Andromeda, of which it is a neighbor in space.

STARS FOR OCTOBER

as seen from latitudes 30° to 50° north, at 10 p.m. and 9 p.m. on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.

OBSERVER'S PAGE

All times mentioned on the Observer's Page are Eastern war time.

BY JESSE A. FITZPATRICK

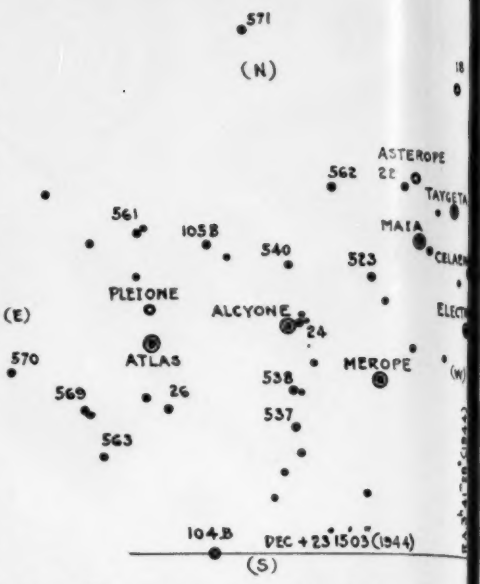
THE PLEIADES RETURN TO THE SKY

THAT interesting group of bright and faint stars, the Pleiades, listed in Messier's catalogue as number 45, is in fine position in October for careful observation and study, especially toward the latter part of the month when the moon rises late and the weather is still mild enough for a long outdoor session.

The diagram, which is drawn as accurately as such a small scale permits, shows the principal stars in the cluster that may be seen with small telescopes, and I have given the usual designations for 25 of them. The numbers that have three digits are of the BD classification; 562 and 571 should be preceded by BD +24°; all other similar numbers should be preceded by BD+23°. The balance of the numbers pertain to the Flamsteed series, but I have omitted these when the star has a mythological name. The omitted numbers are 16, 17, 19, 20, 21, 23, 27, and 28, and belong to the named stars, from west to east, beginning with Celaeno and ending with Pleione. Alcyone's official designation is the Greek letter eta. I mention this in case reference is made to star lists wherein the names are not given. All of the stars are in the constellation of Taurus.

The entertaining article by Dr. Otto Struve, of Yerkes Observatory, in the May issue of **Popular Astronomy,** dealing primarily with the physical characteristics of Pleione, gives some interesting facts about the Pleiades. It is well worth reading. Spectroscopic analysis and long exposure photography being beyond the resources of most amateurs, we shall endeavor to study this group to the extent allowed by our small telescopes. The nebulosity mentioned by Dr. Struve can be detected only by long exposure, so do not expect to see beautiful patterns of glowing cosmic dust such as are observed in the Orion nebula.

Probably the most impressive thing about our first view of the Pleiades in a telescope is the unusual brilliance of most of the stars. This reminds one of the stars in the belt and sword of Orion. The impression results partly from the fact that all but two of the 25 stars I have numbered or named are hot, blue and white stars, belonging to spectral classes **B**5, **B**8, **B**9, and **A**0. The two cooler stars, 571, spectral class **K**5, and 26, spectral class **F**0, do not actually belong to the Pleiades cluster. Their proper motions tell us that at some future date



they will have moved far from their present positions relative to the other stars in the group.

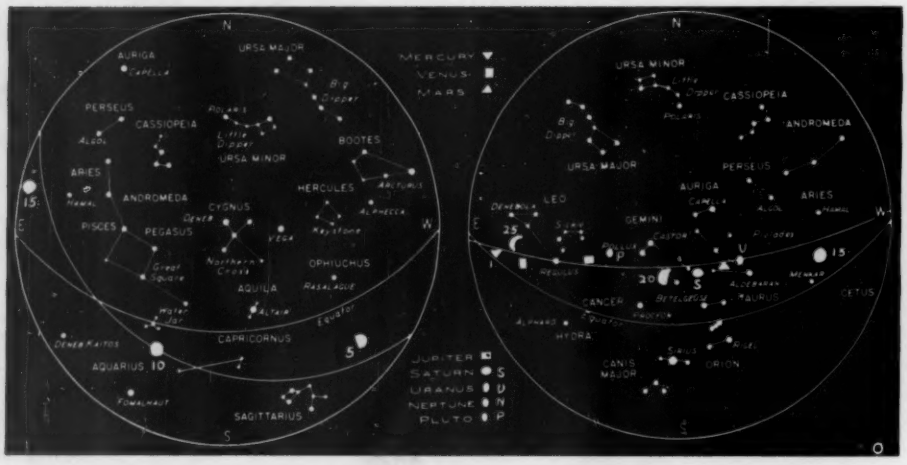
The 23 blue and white stars, plus hundreds of fainter, cooler stars that are not numbered or even shown on the diagram, are of great interest to the professional astronomer; their common distance (500 light-years) and proper motion indicate a common origin. Their proper motion is toward Rigel, to the southeast, about five seconds of arc per 100 years, and may be resolved into three seconds in right ascension and four seconds in declination. In 360 centuries these stars will appear to have moved only the width of the moon!

An interesting comparison may be made with the Hyades cluster, also in Taurus, and only a few degrees from the Pleiades. The Hyades cluster does not contain hot, blue stars, as does the Pleiades, but it does include some red giant stars, in which the Pleiades is completely lacking. The Hyades' stars are about 130 light-years distant, and their motion is slightly more than twice as rapid as that of the Pleiades. Their ultimate goal is at the corner of Orion diagonally opposite from Rigel, toward the star Betelgeuse.

The stars in the Pleiades cluster as shown on the diagram cover an area approximately 1 x 1.5 degrees and are in the position they would be seen when crossing the meridian. To the average naked-eye observer, this position is unusual, because any celestial object 24 degrees north of the equator requires too much craning of the neck to see with ease when near the meridian. We are more familiar with this group as it rises in the east in fall evenings or as it sets in the west in late winter and early spring. Turning the diagram so that the northwest corner is at the top will simulate the eastern position, and northeast at the top will reproduce the western appearance.

Alcyone, magnitude 3.0, is the brightest star in the cluster. I have drawn it, together with five others, Electra, Atlas, Maya, and Merope, all brighter

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 6:30 a.m. on the 7th of the month, and at 5:30 a.m. on the 23rd. At the left is the sky for 8:30 p.m. on the 7th and for 7:30 p.m. on the 23rd. The moon's position is marked for each five days by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury reaches greatest western elongation, 18° 1′, on October 10th. This is a "minimum" value for the elongation, but because of the position of the ecliptic, it will provide a favorable opportunity to see the planet in the eastern sky before sunrise.

Venus reaches greatest brilliance on October 13th; its stellar magnitude will be —4.3. Watch the planet and the moon in the morning skies of October 23rd and 24th. See special articles in the July and August issues.

Mars, in Taurus, will start its retrograde motion on October 27th. At the end of the month its magnitude will be —1.1.

Jupiter is in the morning sky, in Leo.

Saturn and **Uranus** are in Taurus. Saturn will begin its retrograde motion on October 9th.

Neptune is in Virgo.

than 4.4, with a solid center surrounded by a ring. These are the stars usually seen by naked-eye observers, although many claim to see a seventh. Here is an opportunity to settle an age-old dispute by deciding which of the other brighter ones may be seen. Five of these other stars, Pleione, Celaeno, Asterope, 104 B, and 18, I have drawn as large black dots with open centers. They are all brighter than 5.9, Pleione being 5.2 — probably the seventh star visible to keen-eyed persons.

Of these first dozen stars, seven have **B5** spectra and five are **B8**. The remaining stars are all in classes **B9** and **A0**, and all but two are brighter than 7.0. 24 and 538 are 8.1 and 7.1, respectively. There are two visual doubles in the cluster that will test the perfection of small telescopes. 538 has a 9th-magnitude companion, 5″.8 distant, position angle 265°. The companion of 569 is magnitude 9.5, separation 3″.1 and position angle 239°.

As the reader may know, clusters like the Pleiades furnish excellent substantiation of the spectrum-luminosity relation. The hottest and bluest stars are the brightest ones, all appearing to us brighter than 6.0; the others are progressively cooler and fainter, right down to the limit of our largest telescopes.

OCCULTATIONS—OCTOBER, 1943

Local station, lat. 40° 48′.6, long. 4h 55m.8 west.

Date	Mag.	Name	Immersion	P.*	Emersion	P.*
Oct. 4	6.9	BD —19° 4547	8:37.7 p.m.	85°		
6	3.0	Pi Sagittarii	9:36.8 p.m.	139°	10:13.0 p.m.	203°
7	7.3	BD —19° 5731	9:45.4 p.m.	37′		
8	4.2	Theta Capricorni	7:06.7 p.m.	30°	8:02.6 p.m.	303°
8	6.0	BD —18° 5862	7:51.2 p.m.	102°	9:00.7 p.m.	226°
9	4.4	Iota Aquarii	7:42.4 p.m.	71°	8:59.6 p.m.	250°
10	5.6	42 Aquarii	1:48.3 a.m.	78°	2:47.4 a.m.	237°
14	4.4	Mu Ceti	9:34.3 p.m.	12°	10:12.4 p.m.	302°

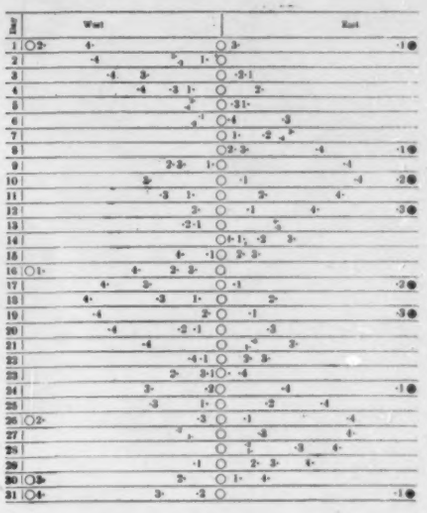
*P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

The planet Jupiter will be occulted by the moon during the early morning hours of October 23rd. Unfortunately, the immersion cannot be observed from any part of the United States, but with perfect atmospheric conditions the emersion might be seen in the easterly half of the New England states. At our local station, moonrise at 1:39 a.m. will precede the emersion by nine minutes, which, of course, can hardly be seen so close to the horizon. The planet will reappear 49° north of the moon's equator, which practically bisects the arc of the crescent. A half or three quarters of an hour later, when the moon is higher in the sky and better placed for observation, Jupiter will still be close enough to the moon's dark limb to present the picture of the Star and Crescent.

At the time of occultation, the configuration of Jupiter's four moons will be of special interest. An approximate line drawn through them will be nearly perpendicular to a line joining the cusps of the crescent moon. At the moment of emersion at our local station, **II**, being west of the planet and close to elongation, will appear first. After Jupiter is fully in the clear from behind the moon's disk, **IV** and **I** will appear very close together and near the planet. **III**, which has been in transit, will emerge on the west of its primary at 2:16 a.m., or about one half hour after the planet emerges.

JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below at 5:45 a.m., E.W.T. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. From the American Ephemeris.



PHASES OF THE MOON

First quarter ..... October 6, 4:10 p.m.
Full moon ..... October 13, 9:23 a.m.
Last quarter ..... October 20, 9:42 p.m.
New moon ..... October 28, 9:59 p.m.

MINIMA OF ALGOL

October 6, 4:07 a.m.; 9, 0:55 a.m.; 11, 9:44 p.m.; 14, 6:33 p.m.; 26, 5:48 a.m.; 29, 2:37 a.m.; 31, 11:26 p.m.

★ ★

PLANETARIUM NOTES

Sky and Telescope **is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.**

★ **THE BUHL PLANETARIUM** presents in *October*, STARS OVER NEW GUINEA. (See page 10.)

There are few of us who do not have a relative or friend serving in the Pacific southwest. This new sky show is designed for all who would like to experience a day and night under the same sky that shines over that distant part of the world. There is the beautiful Southern Cross, of use to navigator of plane or ship. There are the strange Clouds of Magellan. But before we start our journey to New Guinea, the great, round dome of the Planetarium is suddenly transformed into a huge hemispherical map of the earth. On this we get a bird's-eye view of the vast reaches of the Pacific. Visitors can pick out at a glance those places with the strange-sounding names which now are household words — Wake, Bataan, the Solomons, and the rest. Special optical apparatus shows us possible air routes in the Pacific, possible roads to Tokio. On this map we also chart the course we ourselves are going to take. And then — off to New Guinea.

★ **THE HAYDEN PLANETARIUM** presents in *October*, THE SOUTHERN SKY. (See page 10.)

In *November*, TRIP TO THE MOON. By popular request we are repeating this dramatic show, which takes the audience on a rocket ship journey through space to the moon. Landing, watching the sunset and sunrise, seeing an eclipse, witnessing a two-way broadcast back to the earth are only a few of the features in November's trip to the moon.

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Sundays and Holidays.....3, 4, and 8:30 p.m.
(Building closed Tuesdays)

★ STAFF—*Director*, Arthur L. Draper; *Lecturer*, Nicholas E. Wagman; *Manager*, Frank S. McGary; *Public Relations*, Robert F. Hostetter; *Chief Instructor of Navigation*, Fitz-Hugh Marshall, Jr., *Instructor, School of Navigation*, Edwin Ebbighausen.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays .....2, 3:30, and 8:30 p.m.
Saturdays .....11 a.m., 2, 3, 4, 5, and 8:30 p.m.
Sundays and Holidays.....2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator*, Clyde Fisher; *Curator*, William H. Barton, Jr.; *Associate Curator*, Marian Lockwood; *Assistant Curator*, Robert R. Coles (on leave in Army Air Corps); *Scientific Assistant*, Fred Raiser; *Lecturers*, Charles O. Roth, Jr., Shirley I. Gale, John Saunders.